Model 2040 and 2045

High Power Ion Laser

Instruction Manual

Spectra-Physics

Laser Products Division

Model 2040 and 2045

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Instruction Manual

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Laser Products Division
1250 W. Middlefield Road
P.O. Box 7013
Mountain View, CA 94039-7013

International Headquarters
Siemensstrasse 20
D-6100 Darmstadt
F.R. Germany

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Mike

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Preface

This manual contains information you will need for day-to-day operation and maintenance of your Model 2040 high power ion laser system. You will find instructions for safety, installation, operation, maintenance, and service.

NOTE
All references to the Model 2040 also apply to the Model 2045. Any references to the Model 2045, such as tube voltage values and deep UV operation, apply only to the Model 2045 and not to the Model 2040.

While this manual contains a brief installation procedure, it is not intended as a guide to the initial installation and set-up of your laser. Please wait for the Spectra-Physics service engineer who has been assigned this task as part of your purchase agreement. Allow only those qualified and authorized by Spectra-Physics to install and set up your laser system. You will be charged for any damage incurred if you attempt the installation yourself and such action may void your warranty.

The "Service and Repair" section is intended both as an aid to help you guide your Field Service Engineer to the source of problems, and as a guide to repairs you may choose to do yourself. Do not attempt to repair the unit while it is under warranty; instead, report all system failures to Spectra-Physics Customer Service for warranty repair.

The Model 2040 emits laser radiation that can permanently damage eyes and skin. The "Laser Safety" section contains information and guidance about these hazards. To minimize the risk of injury, death, or expensive repairs, carefully follow these instructions.

We welcome feedback concerning the content or style of this manual. The last page is a form to aid in bringing such feedback to our attention. Thank you for your purchase of Spectra-Physics instruments.

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SI Units

The following System International (SI) units, abbreviations, and prefixes are in Spectra-Physics manuals:

Quantity	Unit	Abbrv.	Prefixes
mass	gram	g	tera (10^{12}) T
length	meter	m	giga (10^{9}) G
time	second	s	mega (10^{6}) M
frequency	hertz	Hz	kilo (10^{3}) k
force	newton	N	deci (10^{-1}) d
energy	joule	J	centi (10^{-2}) c
power	watt	W	milli (10^{-3}) m
electric current	ampere	A	micro (10^{-6}) μ
electric charge	coulomb	C	nano (10^{-9}) n
electric potential	volt	V	pico (10^{-12}) p
resistance	ohm	Ω	femto (10^{-15}) f
inductance	henry	H	atto (10^{-18}) a
magnetic flux	weber	Wb	
magnetic flux density	tesla	T	
luminous intensity	candela	cd	
temperature	kelvin	K	

Chapter 1 Introduction

Emission and Absorption of Light*

Laser is an acronym derived from "*l*ight *a*mplification by *s*timulated *e*mission of *r*adiation." Thermal radiators, such as the sun, scatter light in all directions, the individual photons having no definite relationship with one another. But because the laser is an oscillating amplifier of light, and because its output comprises photons that are identical in phase, direction, and amplitude, it is unique among light sources. Its output beam is singularly directional, intense, monochromatic, and coherent.

Radiant emission and absorption take place within the atomic or molecular structure of materials. The contemporary model of atomic structure describes an electrically neutral system composed of a nucleus with one or more electrons bound to it. Each electron occupies a distinct orbital that represents the probability of finding the electron at a given position relative to the nucleus. Each orbital has a characteristic shape that is defined by the radial and angular dependence of that probability, e.g., all "s" orbitals are spherically symmetrical, and all "p" orbitals surround the x, y, and z axes of the nucleus in a double-lobed configuration (Figure 1-1). The energy of an electron is determined by the orbital that it occupies, and the over-all energy of an atom—its energy level—depends on the distribution of its electrons throughout the available orbitals. Each atom has an array of energy levels: the level with the lowest possible energy is called the ground state, and higher energy levels are excited states. If an atom is in its ground state, it will stay there until it is excited by an external energy source.

* *"Light" will be used to describe the portion of the electro-magnetic spectrum from far infrared to ultraviolet.*

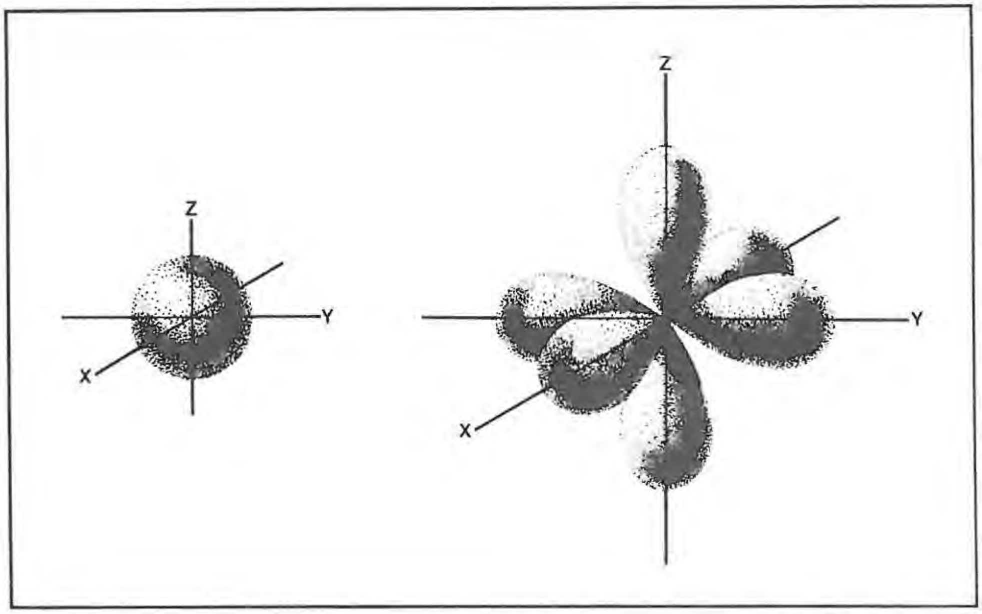


Figure 1-1: Electrons occupy distinct orbitals defined by the probability of finding an electron at a given position, the shape of the orbital being determined by the radial and angular dependence of the probability.

Movement from one energy level to another - a transition - happens when the atom either absorbs or emits energy. Upward transitions can be caused by collision with a free electron or an excited atom, and transitions in both directions occur as a result of interaction with a photon of light. Consider a transition from a lower level whose energy content is E_1 to a higher one with energy E_2. It will only occur if the energy of the incident photon matches the energy difference between levels, i.e.,

$$h\upsilon = E_2 - E_1 \qquad [1]$$

where h is Planck's constant, and υ is the frequency of the photon.

Likewise, when an atom excited to E_2 decays to E_1, it loses energy equal to E_2–E_1. Because its tendency is toward the lower energy state, the atom may decay spontaneously, emitting a photon with energy $h\upsilon$ and frequency

$$\upsilon = (E_2 - E_1)/h. \qquad [2]$$

Spontaneous decay can also occur without emission of a photon, the lost energy taking another form, e.g., transfer of kinetic energy by collision with another atom. An atom excited to E_2 can also be stimulated to decay to E_1 by interacting with a photon of frequency υ, shedding energy in the form of an additional photon that is identical to the incident one in phase, frequency, and direction.

By contrast, spontaneous emission produces photons that have no directional or phase relationship with one another.

A laser is designed to take advantage of absorption, and both spontaneous and stimulated emission phenomena, using them to create conditions favorable to light amplification. The following paragraphs describe these conditions.

Population Inversion

The absorption coefficient at a given frequency is the difference between the rates of emission and absorption at that frequency. It can be shown that the rate of excitation from E_1 to E_2 is proportional to both the number of atoms in the lower level (N_1)and the transition probability. Similarly, the rate of stimulated emission is proportional to the population of the upper level (N_2) and the transition probability. Moreover, the transition probability depends on the flux of the incident wave and a characteristic of the transition called its "cross section". It can also be shown that the transition cross section is the same regardless of direction. Therefore, the absorption coefficient depends only on the difference between the populations involved, N_1 and N_2, and the flux of the incident wave.

When a material is at thermal equilibrium, a Boltzmann distribution of its atoms over the array of available energy levels exists with nearly all atoms in the ground state. Since the rate of absorption of all frequencies exceeds that of emission, the absorption coefficient at any frequency is positive.

If enough light of frequency v is supplied, the populations can be shifted until N_2=N_1. Under these conditions the rates of absorption and stimulated emission are equal, and the absorption coefficient at frequency v is zero. If the transition scheme is limited to two energy levels, it is impossible to drive the populations involved beyond equality; that is, N_2 can never exceed N_1 because every upward transition is matched by one in the opposite direction. However, if three or more energy levels exist, and if their relationship satisfies certain requirements described below, additional excitation can create a population inversion, in which $N_2 > N_1$.

A model four-level laser transition scheme is depicted in Figure 1-2(a). A photon of frequency v_1 excites - or "pumps" - an atom from E_1 to E_4. If the E_4 to E_3 transition probability is greater than that of E_4 to E_1, and if E_4 is unstable, the atom will decay almost immediately to E_3. If atoms that occupy E_3 have a relatively long lifetime, the population will grow rapidly as excited atoms cascade from above. The E_3 atom will eventually decay to E_2, emitting a photon of frequency v_2. Finally, if E_2 is unstable, its atoms will rapidly return to the ground state, E_1, keeping the population of E_2 small and reducing the rate of absorption of v_2. In this way the

population of E_3 is kept large and that of E_2 remains low, thus establishing a population inversion between E_3 and E_2. Under these conditions, the absorption coefficient at υ_2 becomes negative. Light is amplified as it passes through the material, which is now called an "active medium" - the greater the population inversion, the greater the gain.

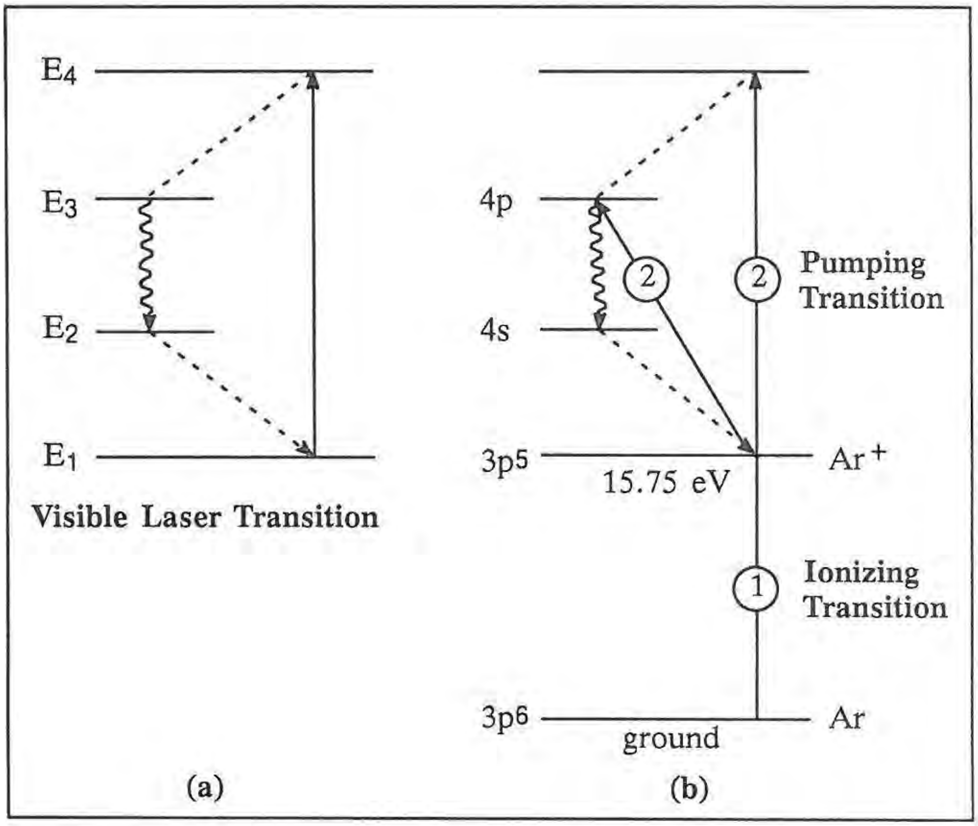


Figure 1–2: A typical four–level laser transition scheme (a) compared to that of visible argon (b). One electron collision ionizes neutral argon, and a second pumps the ion to an excited state.

A four–level scheme, like that described above, has a distinct advantage over three–level systems, in which E_1 is both the origin of the pumping transition and the terminus of the lasing transition. In the four–level arrangement, the first atom that is pumped contributes to the population inversion, while over half of the atoms must be pumped from E_1 before an inversion is established in the three–level system.

In commercial laser designs the source of excitation energy is usually optical or electrical: arc lamps are often employed to pump solid–state lasers; the output of one laser can be used to pump another, e.g., a liquid dye laser is often pumped by an ion laser; and an electric discharge is generally used to excite gaseous media like argon or krypton.

Argon as an Excitation Medium

The properties of argon are probably the best understood of all the ionized gas laser media. Its transition scheme is compared to the model in Figure 1-2(b), and its visible energy level diagram is depicted in Figure 1-3. The neutral atom is pumped to the 4p energy level - the origin of the lasing transition - by two collisions with electrons. The first ionizes the atom, and the second excites the ion from its ground state (E_1) either directly to the 4p energy level (E_3) or to E_4, from which it cascades almost immediately to 4p. The 4p ions will eventually decay to 4s (E_2), emitting a photon either spontaneously or when stimulated to do so by a photon of equivalent energy. The wavelength of the photon depends on the specific energy levels involved, but it will be between 400 and 600 nm. The ion decays spontaneously from 4s to the ionic ground state, emitting a photon in the vacuum ultraviolet - about 74 nm - as it leaves the lower level of the lasing transition.

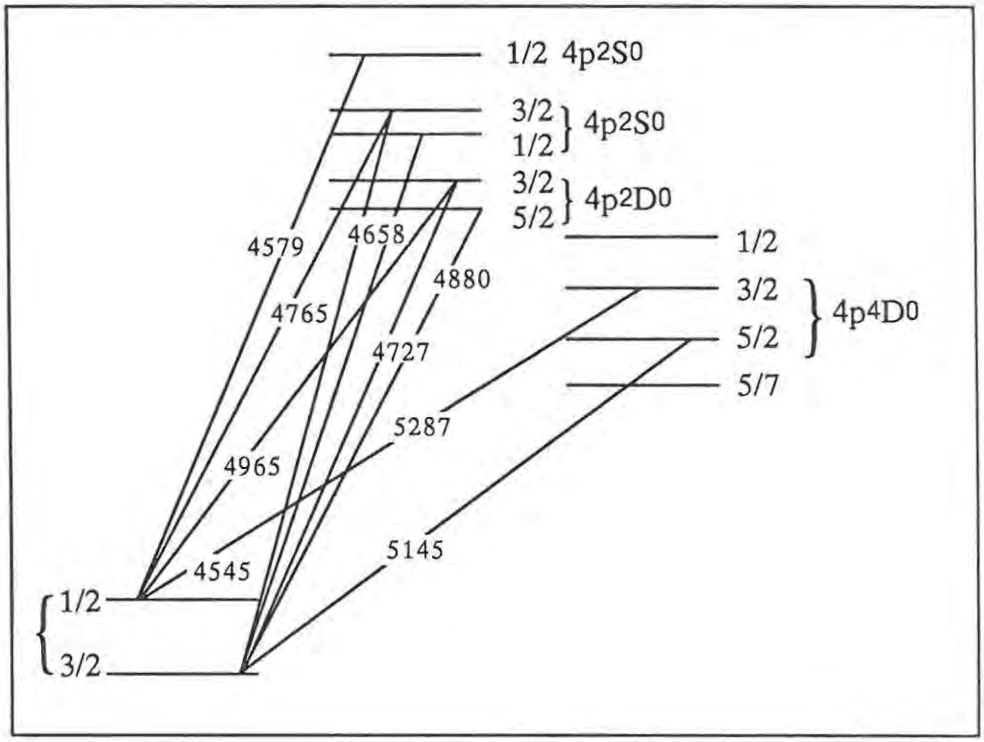


Figure 1-3: Energy Levels of the 4p-4s Argon Ion Laser Transitions

The population in the ionic ground state at any given time is small. Recombination processes return ions to the neutral atom energy level scheme; therefore, there is no tendency toward a self-absorption "bottleneck", a population buildup in the lower laser levels.

The existence of a limited number of lower states for a large number of visible laser transitions suggests that strong competition between lines with common lower levels may exist. Such competition would manifest itself as improved performance for a given line during single-line operation, compared to its strength when all lines are present. Although competition exists, its effect is minor, and single-line operation improves the power of principal lines by less than 10%. Therefore, the use of a prism or other dispersing element in continuous-wave argon ion lasers is not necessarily advantageous, except in single-line applications.

Ion laser gain is directly affected by several factors including discharge current density, magnetic field, and gas pressure. Since two collisions with free electrons are required to pump an argon atom to the upper level of visible lasing transitions, the gain of the medium varies as the square of the current density. Below saturation, the multimode, all-lines output of an ion laser can be expressed as

$$P=kJ^2V \qquad [3]$$

where P is the output power, J is the current density (A/cm^2), V is the volume of the active medium, and k is a constant.

Visible output saturates at a current density of about 800 A/cm^2, while ultraviolet transitions require even higher current densities (see Figure 1–4). UV radiation is a product of transitions between excited states of doubly ionized argon (Ar^{++}), the ground state of which is about 43 eV above that of the neutral atom. By comparison the ground state of singly ionized argon (Ar^{+}) is only about 16 eV above the neutral atom ground state. So two electron collisions, or a single collision with an extremely energetic electron, are required to move between the Ar^{+} and Ar^{++}ground states. If the current density exceeds the saturation point of visible tránsitions the additional energy drives argon ions to the doubly ionized state: UV output appears to rise exponentially with current density to a point beyond the design limit of available exciters.

Ion laser gain is also strongly dependent on gas pressure. For example, argon ultraviolet output is highest at low pressure. Reducing the number of argon atoms increases the time between collisions with free electrons, which increases the average electron energy. This creates conditions favorable to the high energy collisions required to excite argon ions to the Ar^{++}groundstate. Other lines respond better at higher pressures. For optimum performance, gas pressure should be uniform along the length of the discharge region. The pressure-balanced design of the Spectra-Physics plasma tube allows this to happen.

The Resonant Optical Cavity

A resonant optical cavity, which is defined by two mirrors, provides feedback to the active medium. Photons that are emitted parallel to the cavity axis are reflected, returning to interact with other excited ions. Stimulated emission produces two photons of equal energy, phase and direction from each interaction. The two become four, four become eight, and the numbers continue to increase geometrically until an equilibrium between excitation and emission is reached.

Both mirrors are coated to reflect the wavelength, or wavelengths, of interest while transmitting all others. One of the mirrors -the output coupler - transmits a fraction of the energy that is stored within the cavity, and the escaping radiation becomes the output beam of the laser.

For broadband - or "all-lines" - operation, the mirrors reflect a number of lines within a limited wavelength range (about 70 nm maximum). Several sets of broadband optics are available to cover different groups of laser lines.

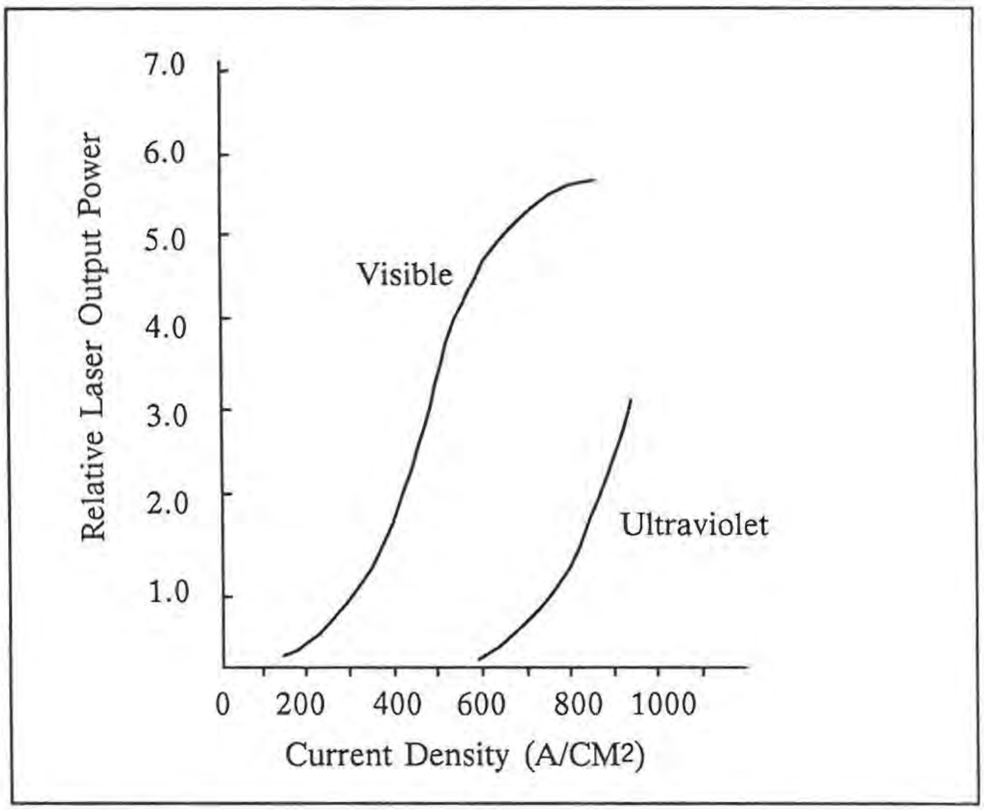


Figure 1-4: Relative output power behavior of singly and doubly ionized argon transitions

Adding a prism to the cavity limits oscillation to a single line. The dispersion of the prism allows only one line to be perfectly aligned with the high reflector, so the tilt of the prism determines which line will oscillate.

The laser oscillates within a narrow range of frequencies around the transition frequency. The width of the frequency distribution–the "linewidth" – and its amplitude depend on the gain medium, its temperature, and the magnitude of the population inversion. Linewidth is determined by plotting the gain of each frequency and measuring the width of the curve where the gain has fallen to one-half maximum (full width at half maximum, see Figure 1-5).

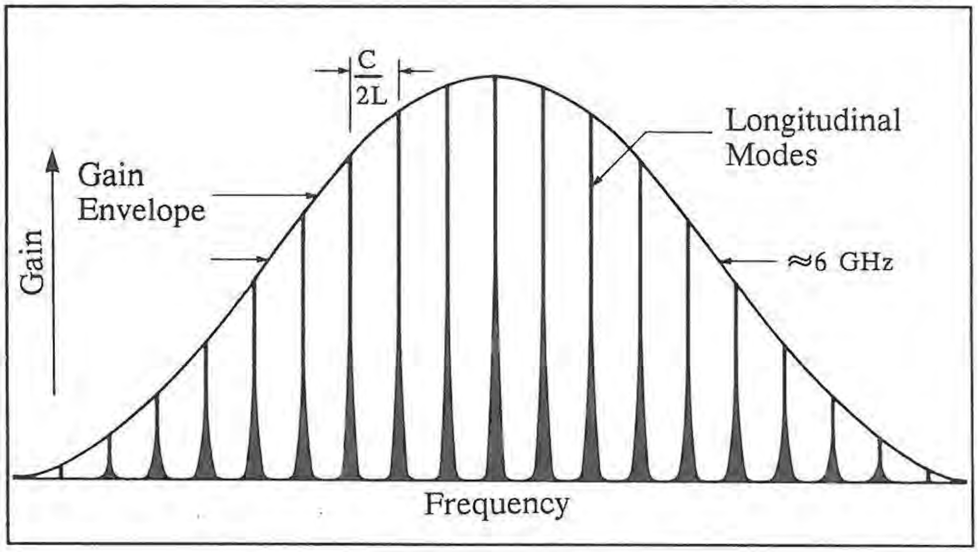


Figure 1–5: Frequency Distribution of Longitudinal Modes for a Single Line

Line broadening depends on the relative velocities of the excited ions as they radiate. If the ion is stationary at the time of stimulated emission, the product photons will possess exactly the transition frequency. If the ion is moving toward the stimulating photon, the resultant frequency will be higher than that of the transition; likewise, if the ion is moving away, the frequency will be lower.

The output of the laser is discontinuous within this Doppler broadened line profile. A standing wave propagates within the optical cavity, and any frequency that satisfies the resonance condition

$$\upsilon_m = mc/2L \qquad [4]$$

will oscillate. υ_m is the frequency, c is the speed of light, L is the optical cavity length, and m is an integer. Thus, the output of a given line is a set of discrete frequencies – called "longitudinal modes" – spaced such that

$$\Delta\upsilon = c/2L. \qquad [5]$$

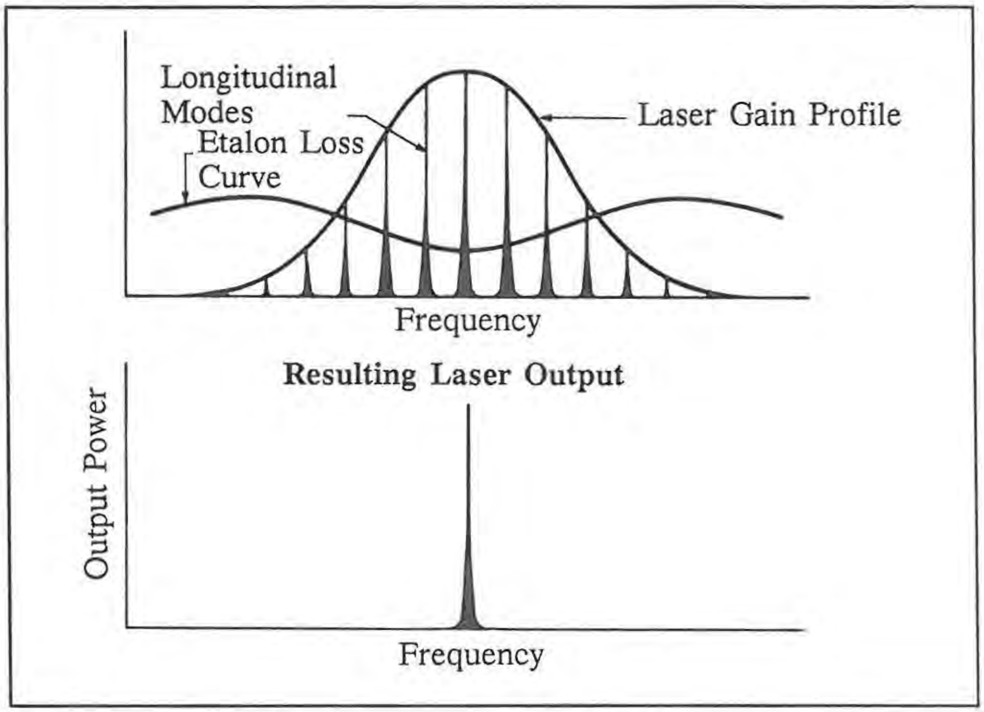


Figure 1-6: Etalon Loss Minimum Tuned to Laser Gain Maximum

An etalon, which is a frequency-selecting element, must be inserted in the cavity in order to isolate lasing to a single longitudinal mode. Spectra-Physics utilizes an optional Fabry-Perot interferometer that acts as a bandpass filter, introducing enough loss in all other modes to prevent them from reaching the lasing threshold (Figure 1-6). The coherence length - the distance over which the output beam maintains a fixed phase relationship - is inversely proportional to the linewidth:

$$l_c = c/\Delta \upsilon. \qquad [6]$$

When the laser output is changed from single line to single frequency, the coherence length increases enormously. If the linewidth is reduced from 6 GHz (single-line) to about 3 MHz (single frequency), the coherence length increases from 50 mm to 20 m.

Resonator Structural Considerations

The stability of the oscillating frequency depends on the design of the resonator structure. Small changes in cavity length, which have several sources including temperature changes and mechanical shifts, will cause corresponding changes in the resonant frequency.

Cavity length changes due to temperature can be expressed as

$$\Delta L = \alpha L \Delta T \qquad [7]$$

where L is the cavity length, α is the thermal expansion coefficient of the resonator structure and ΔT is temperature change. In order to eliminate frequency drift either α or ΔT must be zero. The choice of materials affects the length stability of the structure. The ideal material has both a low thermal expansion coefficient and a high ability to distribute heat evenly, causing a low ΔT along the length of the structure.

Frequency stability also depends on the mechanical rigidity of the resonator structure. Modulation due to "jitter," the microphonic movement of cavity mirrors, can be caused by cooling water flow, external shock to the resonator structure, and acoustic noise. Isolation of the resonator from both the plasma tube, through which the cooling water flows, and the case that surrounds the laser, the source of other vibrations, helps reduce jitter.

The mechanical design of the structure also contributes to jitter-free operation. The most stable configuration is an arrangement of three resonator members in an equilateral triangle (Figure 1–7). As one of the angles increases, the resistance to flexure, in a plane represented by the longest side of the triangle, is reduced. The extreme case, in which all three members lie in the same plane, is the least rigid, its strength coming only from the members themselves. The Model 2040 resonator approaches the ideal equilateral triangle. The graphite rods are enveloped in steel tubes to strengthen the structure and for increased resistance to flexure.

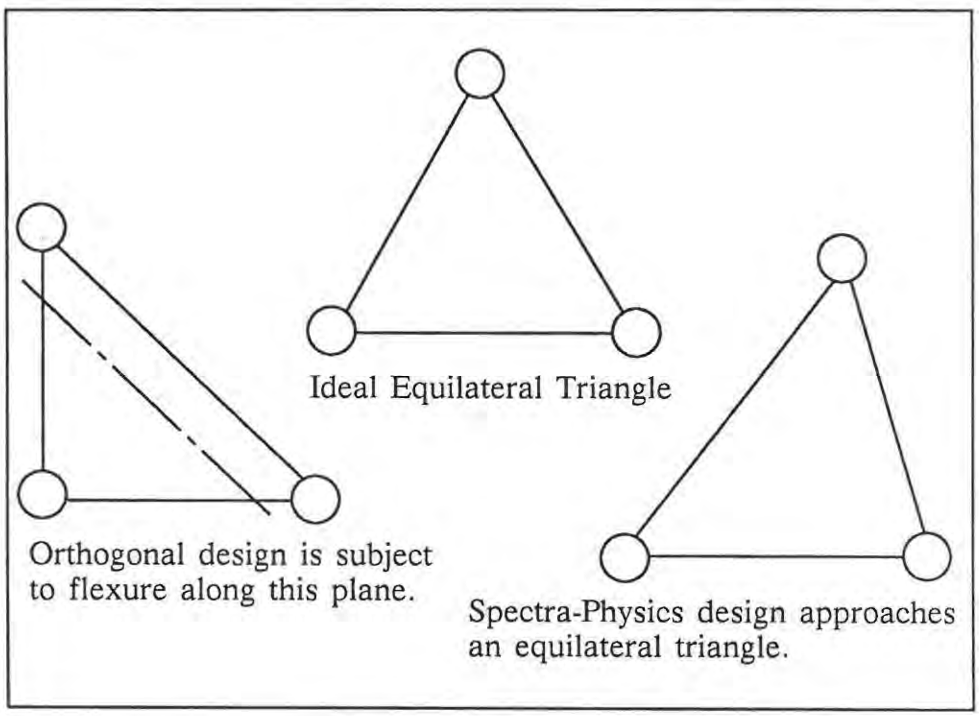


Figure 1–7: The relationship of resonator structural members affects the stability of laser output.

Conclusion

Several factors influence ion laser output. The optical power can be calculated from

$$P_0 = TAI_s \left(\frac{2\alpha_0 L}{T+\beta} - 1 \right) \qquad [8]$$

where T is the output coupler transmission, A is the cross-sectional area of the beam, I_s is a saturation parameter, α_0 is the small signal gain, L is the gain length, and β is the sum of all cavity losses.

The transmission of the output coupler should be the greatest of the cavity losses: it should be greater than the sum of all others. Ideally β, which is caused by unwanted absorption, reflection, diffraction, and transmission, should be zero. Cleanliness of plasma tube processing operations, which eliminates contaminants that can find their way to the inside surfaces of the windows, is essential to improved ion laser output. Cleanliness of other cavity elements, including both mirrors and the outside window surfaces, is also very important. A sealed cavity with a closed loop purge system contributes to overall performance, by maintaining these surfaces in a clean state.

The cross-sectional area, and therefore the volume of the gain region can be increased by enlarging the bore and using a long radius output coupler (Figure 1-8). The use of long-radius optics requires an extremely rigid resonator structure. Increasing the mode volume of the cavity while maintaining a constant current density increases the laser output power.

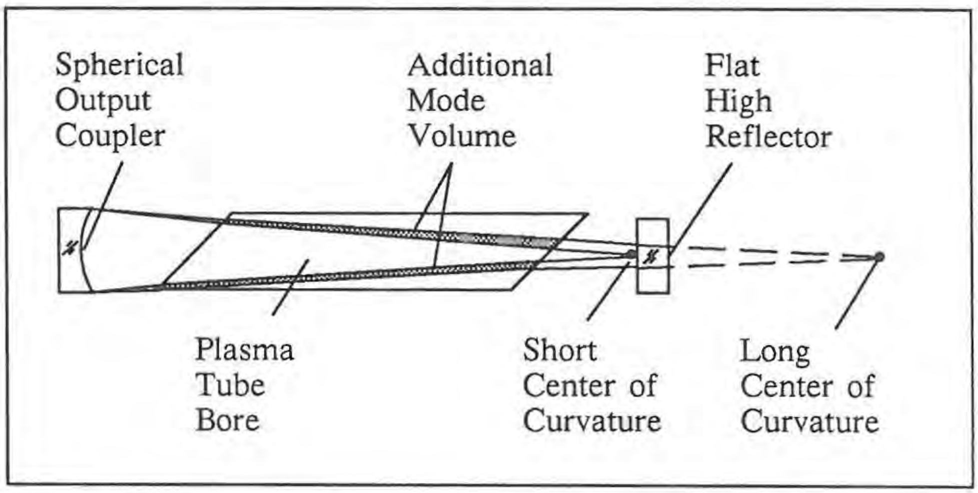


Figure 1-8: Lengthening the radius of curvature of the output coupler enhances output by increasing the mode volume of the cavity.

The Spectra-Physics Model 2040 ion laser represents another major step in the evolution of laser technology. With its advanced plasma tube design, high-field magnet, thermally compensated graphite composite resonator, and all new high-current power supply, it is a system that delivers visible and UV output to match the most exacting standards.

System Description

The Model 2040 high power ion laser system consists of the Model 2040 laser head, the Model 024 plasma tube, the Model 2570 power supply, and the Model 2470 remote control module. These components make up a high power laser system that is extremely reliable and convenient to use.

The Model 2040 laser head comprises the long frame mechanical resonator, the Model 024 plasma tube, and a new magnet. The resonator is temperature compensated, extremely rigid, and optically stable. This resonator, along with the 024 plasma tube, combine to provide a system with excellent beam pointing characteristics.

The Model 024 plasma tube incorporates the latest in cold disc metal ceramic technology and patented Q-M Endbells™, which prolong the tube lifetime by eliminating internal window contamination. In Q-M Endbells™, a patented window coating protects the window from long-term UV radiation damage, and a modified optical contact bond is used to seal the window to the endbell assembly. This essentially eliminates residual contamination inherent in traditional "hard seal" bonding agents. The new gas fill system automatically keeps the tube filled to either the threshold fill level or to a safety fill level; the levels are selectable by a switch on the laser head. The internal pressure equalization system and the clean room assembly techniques mean this tube will provide a long and trouble-free lifetime.

The Model 2570 power supply is compact in size and convenient to use. The patented switched resistor technology provides regulated power to run the system. A wide range power stabilization circuit produces stable output power and low noise operation. The power supply houses a built-in intracavity air purifier that keeps contaminants off of the plasma tube windows and mirror surfaces, which reduces periodic maintenance.

The Model 2470 remote control module offers current and power mode controls, digital display of current, voltage or power, and status indicators for all interlock functions. The power meter has five sensitivity ranges from 0.3 W up to 30 W and provides continuous power readings. There is also an analog meter to assist in tuning up the laser. The remote module attaches to the power supply by a cable to allow for placement in a convenient location.

Specifications[1]

Optical Characteristics		
Noise[2]	—Current Mode	0.4% rms
	—Light Mode	0.3% rms
Stability[3]	—Current Mode	<3.0%
	—Light Mode	<0.5%
Beam Diameter[4,5] at $1/e^2$ points		1.65 mm
Beam Divergence[5] at 514.5 nm		0.5 mrad
Cavity Length	—without prism	1.71 m
	—with prism	1.78 m
Mode Spacing	—without prism	87 MHz
	—with prism	84 MHz
Polarization		>100:1 vertical

Utilities	
Electrical	
Input Power	3 phase with ground
Voltage	480 V ± 8%
Current	73 A
Frequency	50/60 Hz
Water	
Water Flow Rate (minimum)	19.0 1/min (5.0 US gal/min)
Differential Pressure[6] (minimum)	4.3 kg/cm^2 (60 psig)
Leakproof Inlet Pressure (maximum)	5.3 kg/cm^2 (75 psig)
Maximum Inlet Temperature	35°C (95°F)

Physical Dimensions		
Laser Head	—size	189.31 x 24.13 x 20.64 cm (74.53 x 9.50 x 8.13 in.)
	—weight	100.0 kg (220 lb)
Power Supply	—size	68.58 x 52.71 x 37.21 cm (27.00 x 20.75 x 14.65 in.)
	—weight	79.5 kg (175 lb)

1. *Specifications subject to change without notice.*
2. *Performance at 514.5 nm, 10 Hz–2 MHz, Argon.*
3. *In any 30 min period after a 2 hr warm-up.*
4. *Data for 514.5 nm; at other wavelengths, assuming no change in optical configuration, the diameter is given by:* $\frac{DIA_1}{DIA_2} = \left(\frac{\lambda_1}{\lambda_2}\right)^{2\,1/2}$
5. *Cavity configuration—flat high reflector and 8 m radius output coupler.*
6. *Defined as the difference between the exit back pressure and the input pressure.*

Output Power[1]

Wavelength, nm	Model 2040-15	2040-20	2040-25	2045-15	2045-20	2045-25
Multiline[2]						
457.9–514.5	15 W	20 W	25 W	15 W	20 W	25 W
333.6–363.8	—	—	—	2.5-3.5	3.0-4.5	3.5-7.0
275.4–305.5	—	—	—	0.35-0.50	0.50-0.70	0.50-1.50
Single-line[3]						
528.7	1.0	1.4	1.8	1.0	1.4	1.8
514.5	7.0	9.0	10.0	7.0	9.0	10.0
501.7	1.0	1.4	1.8	1.0	1.4	1.8
496.5	1.8	2.4	3.0	1.8	2.4	3.0
488.0	5.5	6.5	8.0	5.5	6.5	8.0
476.5	1.8	2.4	3.0	1.8	2.4	3.0
472.7	0.6	1.0	1.3	0.6	1.0	1.3
465.8	0.4	0.6	0.8	0.4	0.6	0.8
457.9	1.0	1.4	1.5	1.0	1.4	1.5
454.5	0.4	0.6	0.8	0.4	0.6	0.8

1. *Specifications subject to change without notice.*
2. *All multiline powers, except multiline visible, are TEM_{OO}.*
3. *Single-line powers for argon lasers are specified at 514.5 nm and 488.0 nm. Powers of all other lines indicated are nominal. Firm specifications require special testing and are only available at the time of purchase. All output power specifications, except multiline visible, refer to TEM_{OO} operation, which is determined by scanning the beam with a pinhole intensity profiler and selecting the largest aperture that provides a Gaussian intensity profile in the far field.*

Chapter 2 Laser Safety

DANGER
The Spectra-Physics Model 2040 Laser is a Class IV–High Power Laser whose beam is, by definition, a safety and fire hazard. Take precautions to prevent accidental exposure, to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage.

Precautions for the Safe Operation of Class IV–High Power Lasers

- To avoid unnecessary radiation exposure, keep all protective covers in place during normal operation.
- Do not attempt to view either a direct or reflected beam; even a diffuse beam reflection may be hazardous.
- Use protective eyeware at all times; selection depends on the wavelength and intensity of the radiation, the conditions of use, and the visual function required. Worldwide vendors for protective eyeware are listed in the *Laser Focus and Lasers and Optronics Buyer's Guide*. Consult the ANSI, ACGIH, or OSHA standards listed at the end of this section for guidance.
- Avoid intercepting direct or reflected beams with any part of the body.
- Establish a controlled–access area for laser operation. Limit access to those persons who are trained in laser safety principles.
- Maintain a high ambient light level in the laser operation area so that the eye's pupil remains constricted, reducing the possibility of damage.
- When operating in the UV range, provide adequate ventilation to reduce the hazard of toxic contamination due to bombardment of atmospheric elements by the laser beam.

- Post warning signs prominently near the laser operation area (Figure 2-1).
- Set up experiments so the laser beam is either above or below eye level.
- Provide enclosures for beam paths whenever possible.
- Set up a beam block to capture the laser beam and prevent accidental exposure.
- Set up shields to prevent stray reflections from escaping the laser operating area.

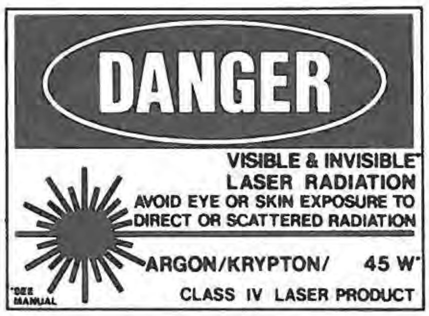


Figure 2-1: Standard Safety Warning Sign

DANGER
Use of controls or adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure.

Operating this laser without due regard for these precautions or in a manner that does not comply with recommended procedures may be dangerous. At all times during installation, maintenance or service of your laser, avoid unnecessary exposure to laser or collateral radiation* that exceeds the accessible emission limits listed in "Performance Standards for Laser Products," *United States Code of Federal Regulations*, 21CFR1040.10(d).

Follow instructions contained in this manual for proper installation and safe operation of your laser.

**Any electronic product radiation, except laser radiation, emitted by a laser product as a result of or necessary for the operation of a laser incorporated into that product.*

Schedule of Maintenance Necessary to Keep this Laser Product in Compliance with Center for Devices and Radiological Health (CDRH) Regulations

This laser product complies with Title 21 of the *United States Code of Federal Regulations*, Chapter 1, Subchapter J, Parts 1040.10 and 1040.11, as applicable. To maintain compliance with these regulations, once a year or whenever the product has been subjected to adverse environmental conditions (e.g., fire, flood, mechanical shock, spilled solvent), check to see that all features of the product identified on the radiation control drawing (Figure 2-3) function properly. Also, make sure that all warning labels remain firmly attached.

1. Verify that removing the AUXiliary INTERLOCK connector prevents laser operation.
2. Verify that the laser can only be turned on when the key switch is in the on position, and that the key can only be removed when the switch is in the off position.
3. Verify that the emission indicator provides a visible signal when the laser emits accessible laser radiation that exceeds the accessible emission limits for Class I*. Also verify that the signal provides an advance warning sufficient to allow action to avoid radiation exposure.
4. Verify that the beam attenuator actually blocks access to laser radiation.
5. Verify that the safety interlock stops emission of laser or collateral radiation upon removal or displacement of the interlocked part of the protective housing.
6. Verify that, when the safety interlock is defeated, the defeat key is clearly visible and prevents replacement of the cover while in place.

Laser Head and Power Supply Cover Interlocks

Model 2040 has safety interlocks in both the laser head cover and power supply cover. Removing either of these covers opens a circuit in the power supply, which in turn opens the main power contactor, shutting off electrical power to the laser. The covers must be on or the interlocks defeated before the laser will operate.

**0.39 μW for continuous-wave operation where output is limited to the 400 to 1400 nm range.*

In the laser head, when the interlock defeat key has been installed, the laser can operate with the cover removed. Be extremely careful to avoid high voltage terminals and unnecessary exposure to laser or collateral radiation.

The laser head cover cannot be replaced until the interlock defeat key has been removed. Shut off the laser before exchanging the interlock key and cover.

The power supply cover interlock switch can be pulled up to defeat the interlock. Be extremely careful to avoid contact with high voltage inside the power supply if it is operated with the cover off.

Figure 2–2: Safety Interlock Key

DANGER: HIGH VOLTAGE AND CURRENT
Both the Model 2040 laser head and its power supply contain electrical circuits operating at lethal voltage and current levels. Exercise extreme caution whenever the protective cover is removed from the laser head or power supply, or when the hatch cover is open. Do not touch high voltage terminals or components.

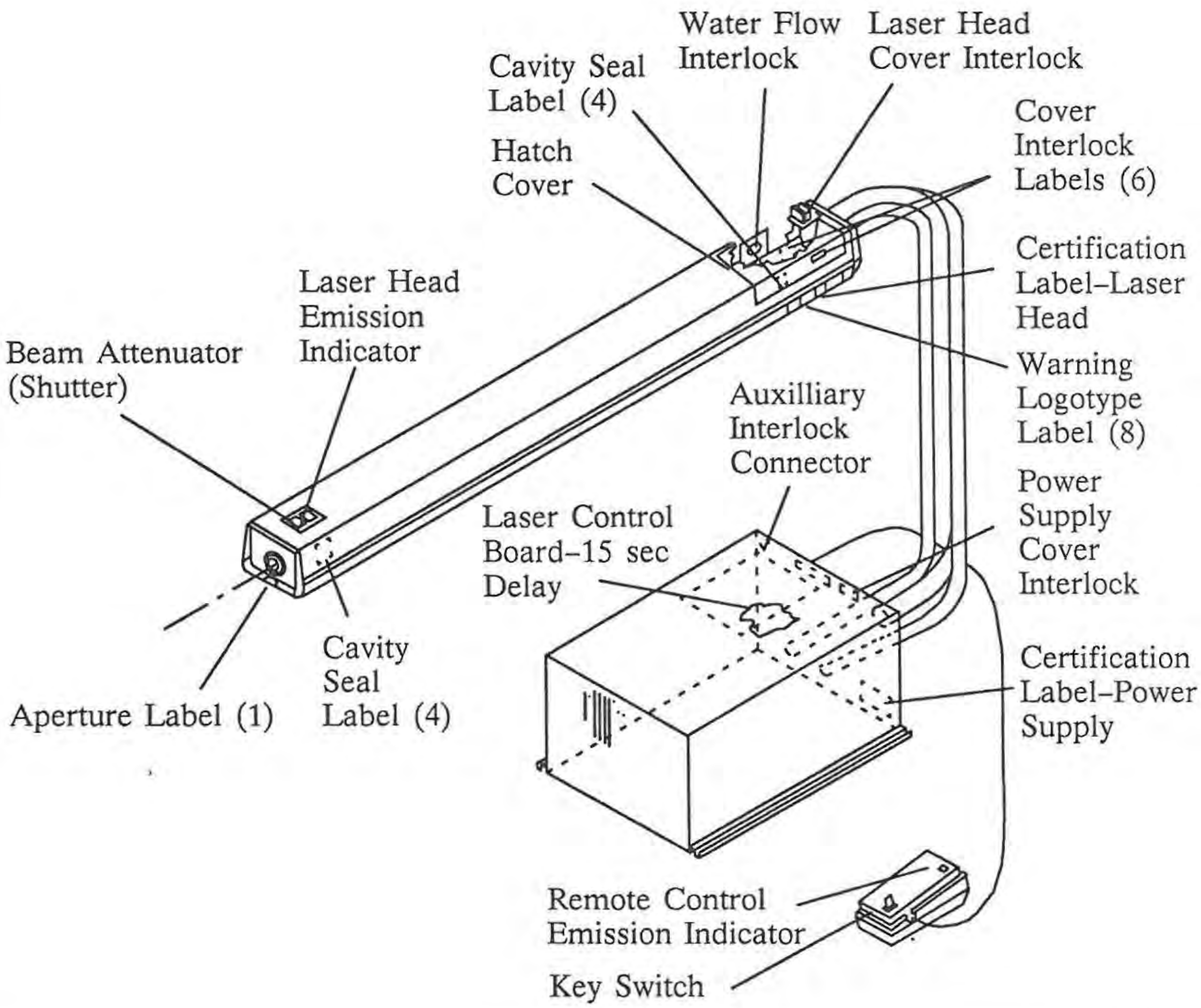
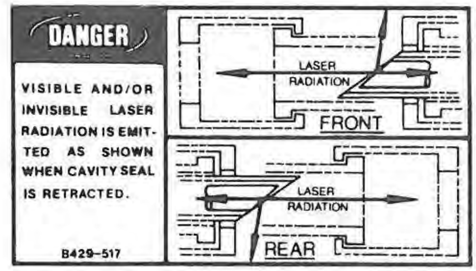


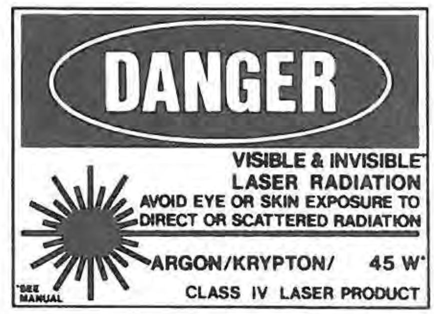
Figure 2–3: Radiation Control Drawing (0437-4100, rev. 1)

Aperture Label (1)



Cavity Seal Label (4)

Cover Interlock Label (6)



Warning Logotype Label (8)

Figure 2-4: Model 2040 Warning Labels

Sources of Laser Safety Standards

"Safe Use of Lasers" (Z136.1)
American National Standards Institute (ANSI)
1430 Broadway
New York, NY 10018

"A Guide for Control of Laser Hazards"
American Conference of Governmental and Industrial Hygienists (ACGIH)
1014 Broadway
Cincinnati, OH 45202

Occupational Safety and Health Administration (OSHA)
U.S. Department of Labor
400 1st Street N.W.
Washington, DC 20001

Chapter 3 Installation

Unpacking your Laser

Inspect each component of the system carefully as you unpack it. If you notice any damage, such as dented or scratched covers, broken knobs or switches, notify the shipper and your Spectra-Physics sales representative immediately. If, upon installation, the laser fails to operate or meet performance specifications, Spectra-Physics will arrange for repair or replacement without waiting for your claim against the carrier to be settled.

Keep the shipping containers. If you file a damage claim, you may need it to demonstrate that the damage occurred as a result of shipping. If you need to return the laser for service, the specially designed containers assure adequate protection.

You will find the following items in the accessories kit in which this manual was packed:

- a tool kit that contains all of the tools you will need to align and maintain your laser, including various Allen wrenches and drivers for beam alignment, a hemostat and lens tissue for optics cleaning, a dispensing bottle, the prism assembly, any optional optics assemblies, and a set of table clamps;
- two water hoses for the cooling system—you will need one hose for water service and one for the drain;
- a filter for the water supply and two extra cartridges;

You will need to supply several items, including:

- electronic grade, or better, acetone and methanol for optics cleaning;
- several ball drivers for plasma tube alignment; the Allen wrench set supplied with the laser is adequate, but a set of ball drivers that includes one #28 (1/4 in.) and four to six #23 (3/32 in.) wrenches makes alignment much simpler.

> *NOTE*
>
> The following installation procedures are provided for reference only; they are not intended as guides to the initial installation and set-up of your laser. Please call your Spectra-Physics service representative to arrange an installation appointment, which is part of your purchase agreement. Allow only those qualified and authorized by Spectra-Physics to install and set up your laser. You will be charged for any damage incurred if you attempt to install the laser yourself and such action may void your warranty.

Electrical Connections

The power supply requires three–phase electrical service rated at 480 V (±8%) and 90 A, the maximum operating current is 73 A per phase rms. The switch box should be less than 3.5 m (12 ft) from the power supply. Connect the green lead of the power cord to *earth ground*, not neutral. Connect the remaining three leads to the legs of the three-phase service; the sequence is not important. If a quick–disconnect plug is used, it must be rated for at least 90 A.

Connecting the Laser Head Umbilical to the Power Supply

1. Place both the laser head and power supply in their operating positions; the power supply must be less than 3.6 m (12 ft) from the laser head (the length of the umbilical cable.)
2. Remove the power supply cover.
3. Secure the metal flange of the umbilical to the rear panel of the power supply using four screws. (Figure 3–1)
4. Plug the large four-prong plug into the socket in the power supply.
5. Connect the Control Signal cable and the Medium Power signal cable to their matching receptacles.
6. Connect the two purge line connectors to the matching color receptacles. The built-in purge system operates whenever the incoming power to the power supply is on.
7. Install the power supply cover.

Figure 3–1: Model 2570 power supply showing locations for umbilical connections.

Water Connections

Cooling water may be supplied from an open–loop system consisting of a tap water source and direct connection of the outflow to a drain, provided the water flow rate is at least 19.0 l/min (5.0 US gal/min) at a differential pressure* of at least 4.3 kg/cm (60 psig). The diameter of the incoming water service line should be at least 15.9 mm (5/8 in.) All hose connections are U.S. garden hose variety.

The laser head should be mounted horizontally for optimal water cooling. If you plan to mount the laser head in any other orientation, contact your Spectra–Physics service representative for information.

1. Install the water filter in the water supply line; the direction of flow is marked on the filter case.
2. Connect the filtered water supply to the WATER IN fitting on the rear panel of the power supply.
3. Connect the hose from the umbilical that matches the WATER TO HEAD fitting on power supply.

**defined as the difference between the exit back pressure and the input pressure*

4. Connect the remaining umbilical hose to the water drain line. Make sure the water hoses are not kinked or restricted at the laser head or power supply.

DANGER
Make sure the cooling water goes to the power supply first and then to the laser head. Operating the power supply without cooling water will cause severe damage to the supply.

The cooling water in most locations is of adequate quality, so scale build-up on the plasma tube will not be a problem. However, if the cooling water has a concentration of dissolved solids greater than 150 ppm, we strongly recommend the use of a closed loop water conditioning system. Failure to use a water conditioner can lead to reduced cooling efficiency and possible damage to the plasma tube.

Table 3-1: Model 2040 Ion Laser Thermal Parameters

Maximum Required Heat Dissipation:	57 kW
Required Coolant Flow Rate:	19.0 l/min (5.0 US gal/min)
Maximum Coolant Inlet Temperature:	35° C (95° F)
Required Coolant Differential Pressure:	4.3 kg/cm^2 (60 psig)
Maximum Coolant Inlet Pressure:	5.3 kg/cm^2 (75 psig)

Unpacking the Laser Head Interior

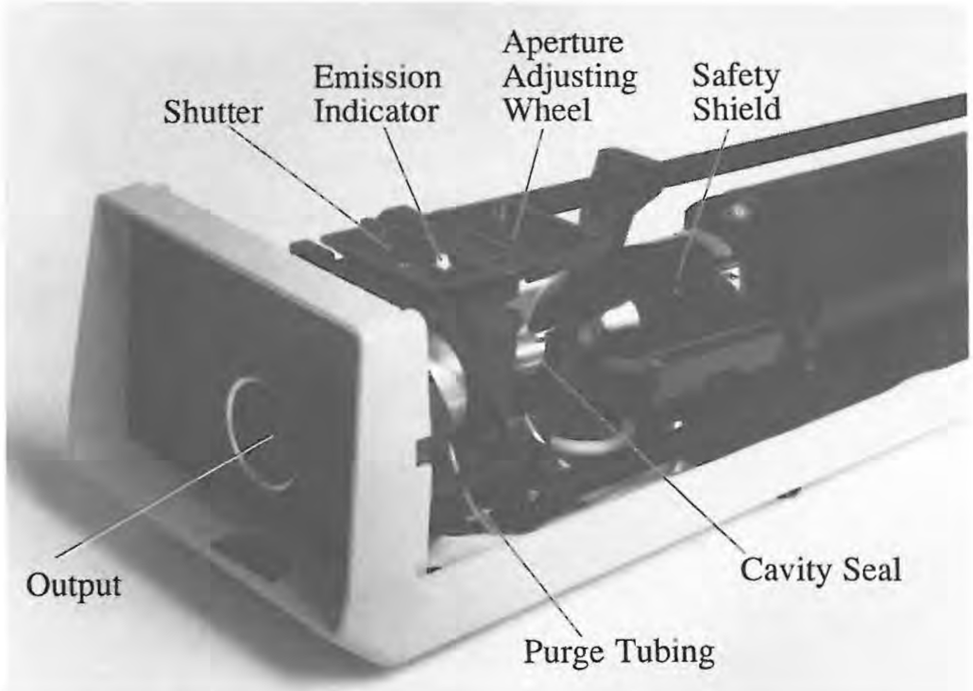


Figure 3–2: Laser Head Interior (Output End)

Several precautions were taken when your laser was prepared for shipping. Remove the laser head cover and inspect the interior.

1. Inspect the cavity seal on each end of the plasma tube. If the seal was dislodged during shipping, the plasma tube window will have to be cleaned; refer to "Service and Repair: Cleaning the Plasma Tube Windows" for details.
2. Inspect the gas purge system feeder tubes. Be sure the gas purge tubing is securely attached to all fittings.
3. Inspect the shutter and aperture. Both should be fully open. The numbered positions on the aperture wheel indicate available apertures with "12" the largest. "O" on the shutter switch indicates that the shutter is open.
4. Replace the laser head cover.

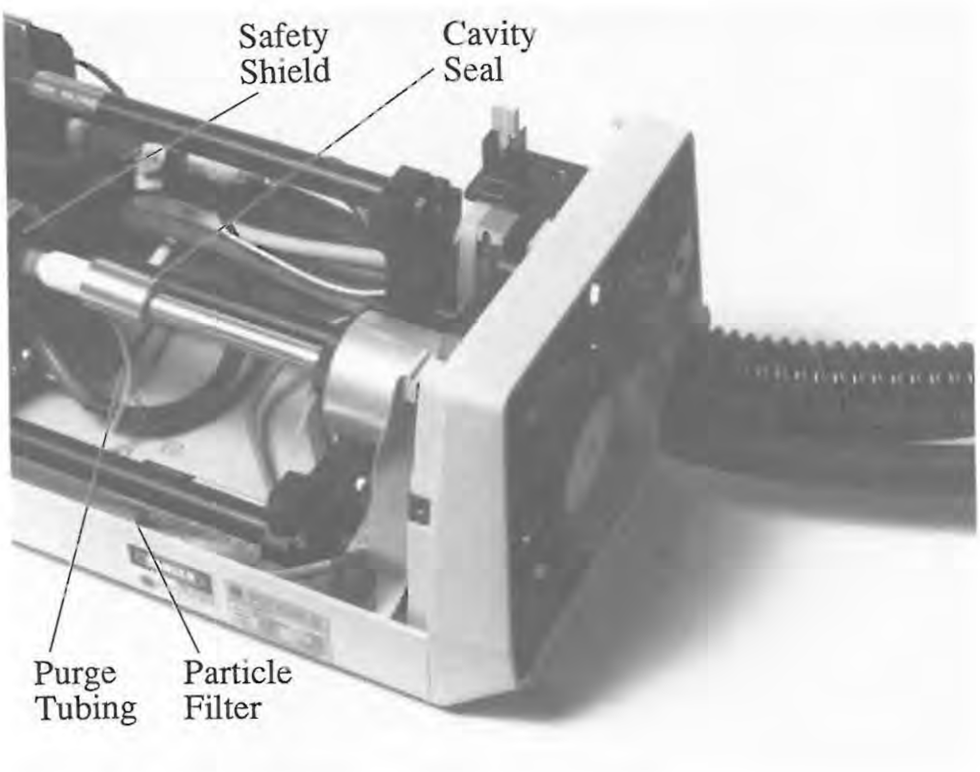


Figure 3-3: Laser Head Interior (High Reflector End)

Intracavity Air Purifier

The intracavity air purifier operates continuously when wall power to the system is turned on. The air purifier is a closed-loop system that supplies a constant flow of filtered air to the laser head intracavity spaces. This air flow removes dust particles, ozone, and contaminating vapors from the intracavity space, preventing loss of output power caused by contamination of optical surfaces. The purge eliminates the need for frequent optics cleaning to maintain long-term output power stability.

The purge system, including the pump motor and filter, is located in the power supply. The condition of the purge filter is visible on the rear panel of the power supply. When the purge filter dessicant turns pink or red, it must be replaced. Refer to "Maintenance: Changing the Purge Filter" for instructions.

Particle Filter in Laser Head

A particle filter, located in the laser head near the high reflector end, is connected in series with the purge tubing. The direction of air flow is marked on the outside of the case. Under normal operating conditions this filter does not need replacement.

Water Testing the Plasma Tube

The following procedure should be performed (to check for water leaks) before operating the laser for the first time.

1. Remove the laser head cover.

2. Slowly open the water supply valve until you hear the water begin to flow.

3. Check for leaks at both ends of the magnet, at all plumbing connections within the laser head, and around the umbilical connection at the rear of the power supply. Check for water drops beneath the power supply.

4. If leaks are present, check the O-ring seals and hose washers at the locations mentioned above for proper seating. If leaks persist, shut off the water supply, drain the cooling system, and call your Spectra-Physics service representative.

Adjusting the Height of the Laser Head

The laser head rests on four adjustable feet. The head can be raised or lowered by loosening the threaded retaining ring and screwing the feet in or out. The feet should all be the same height, especially from side to side; their heights must be within 0.3 cm (1/8 in) of one another. Tighten the retaining rings when the adjustments are complete.

Chapter 4 Remote Control Interface

The Model 2570 power supply is operated from a remote control module that connects to the power supply through the (REMOTE) connector, which is located on the connector panel of the power supply. This connector provides access to analog and TTL logic signals that are used to control the power supply and laser head and monitor their status. A complete functional description of these signals is given later in this section of the manual.

The Model 2470 remote control module is an accessory that attaches through a 37-conductor interface cable to the REMOTE connector of the power supply. The remote control module allows the user to turn the laser on or off, select the power supply operating mode (current or power), and adjust the setpoint for the tube current or power output. It also provides readouts of the interlock, emission, and fill status, and gives a digital display of current, power, or voltage.

Figure 4–1: Model 2470 Remote Control Module

Model 2470 Remote Control Module Controls and Indicators (Figure 4–2)

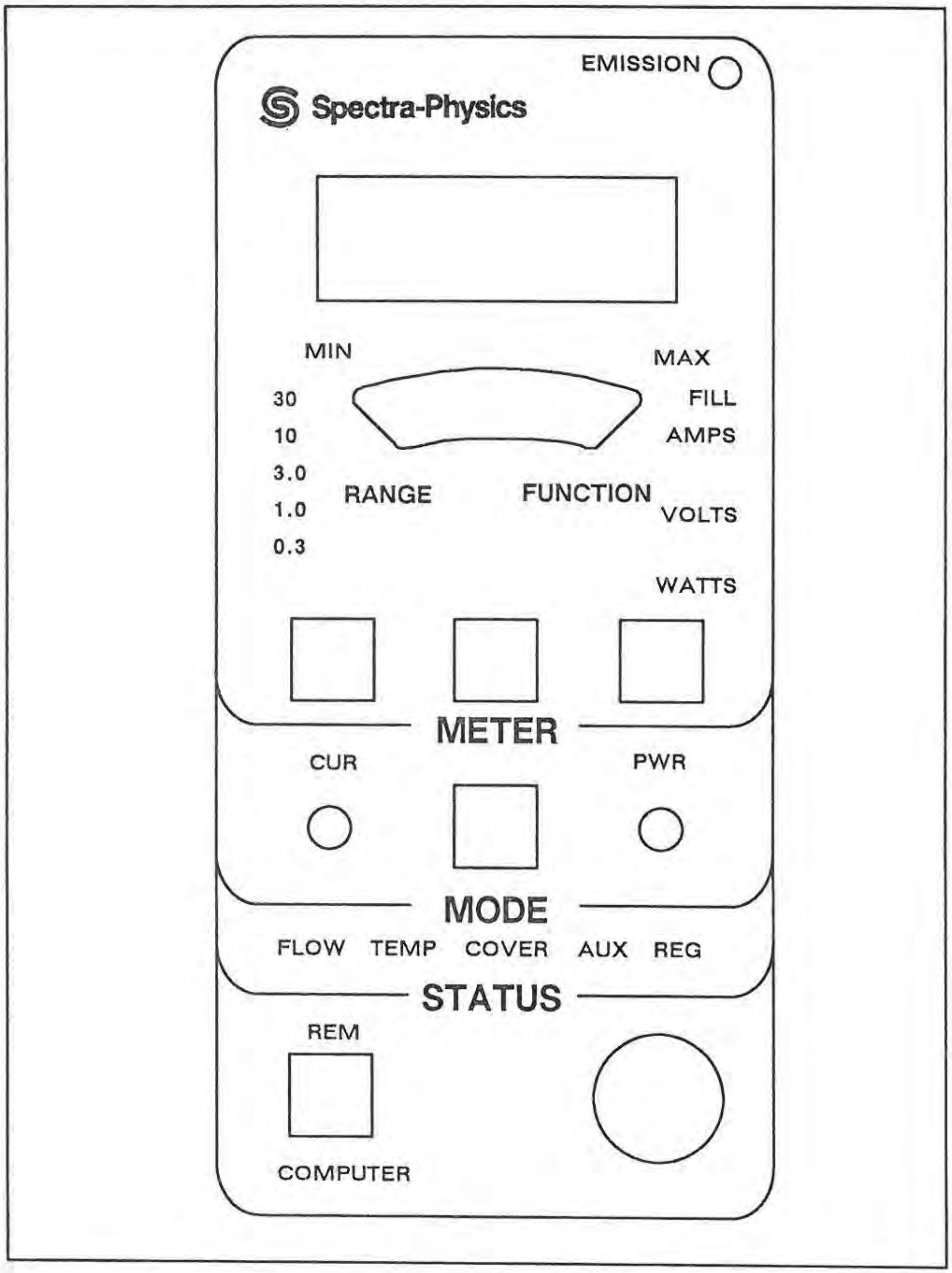


Figure 4–2: Model 2470 Showing Location of Indicators and Ranges

Interlock STATUS Indicators

These indicators are not visible unless the interlock is open, which results in the power supply turning off. When the indicator is visible, the interlock is open.

FLOW indicator–glows when the water flow rate through the laser head is less than 5.0 gal/min.

TEMP indicator–glows when the temperature of the water exiting the laser head exceeds 78° C (172° F).

COVER indicator–glows when the cover interlock switch in the laser head is open.

AUX indicator–glows when the auxiliary interlock circuit is open. The auxiliary interlock connector is located on the connector panel of the power supply.

REG indicator–glows when the system shuts off due to one of the following reasons:

- current to the laser head exceeds the maximum safe operating limit of 65 A.
- a fault has been detected in the power supply.
- the plasma tube has run out of gas or for some other reason cannot be filled and the resulting low tube pressure makes the laser unsafe to operate. The FILL indicator blinks on and off in this condition.

In each of the above cases, when the REG indicator comes on, you must call your Spectra-Physics service representative.

FILL Indicator

This indicator glows when the fill system is filling the tube. If the autofill switch, located on the laser head, is turned on, the fill system fills the tube when the actual tube voltage drops below the fill threshold level.

If the autofill switch is turned off, and the actual tube voltage drops to less than the safety fill level (96% of the fill threshold level), the fill system overrides the autofill off command and fills the tube back to the 96% level.

If, after 15 min of trying to fill, the fill system is unable to raise the tube voltage to either the fill threshold level (when autofill is on) or the 96% level (when autofill is off), the power supply will turn off and the FILL indicator will flash on and off to indicate that the laser can no longer be operated due to low tube voltage. You must call your Spectra-Physics service representative when this condition occurs.

EMISSION Indicator

This indicator glows when the key switch is turned on and the laser head is capable of emitting laser radiation. All interlocks must be closed before the laser can be turned on.

Switches

Key switch—turns the laser on and off. Turning the key switch one-quarter turn clockwise to the "on" position turns on the emission indicators on the remote control module and on the laser head. After a 15 sec safety delay, laser emission starts.

REMOTE/COMPUTER switch—toggles the power supply control source between remote and computer. When the REMOTE indicator is on, the Model 2470 remote control module is the control source for the power supply.

When the COMPUTER indicator is on, the control source is a computer or terminal connected through the optional Model 2680 computer interface board. Under computer control, the power range switches and the current and power control knobs on the remote module are disabled; however, the range and mode indicators and the digital and analog meters continue to monitor the status of the system.

As a safety precaution the REMOTE/COMPUTER switch can be disabled so that either one or the other control states is always active. See the section on internal dipswitch settings in this chapter.

MODE Switch and Control Knobs

MODE switch—toggles the active mode between CURrent and POWeR. When the indicator is turned on, that mode is active. The MODE switch is disabled when the system is operating under computer control.

- in current control mode, the plasma tube current is held constant at the level set by the current control knob.
- in the power control mode, the power supply adjusts the plasma tube current to maintain constant optical output power at the value set by the power control knob.

Current control knob—sets the plasma tube current, when the system is in current mode. The power supply limits the rate at which the current can be increased between 55 A and 65 A. If the system is operating under 44 A and the current is increased quickly above 55 A, the limiting circuit sets the current rise to about 1 A per sec between 55 A and 65 A.

If the system is operating above 44 A, the current limit does not affect the rate of current increase.

Power control knob—sets the optical output power when the system is in power mode. The rate at which the power can be increased is subject to the same dynamic current limit as mentioned under the current control knob. If the power control knob is turned up quickly from a power level requiring less than 44 A to a level requiring greater than 55 A, the power increase is limited to a rate equivalent to about 1 A per sec.

METER Function and Range Switches

METER function switch—selects either the WATTS, VOLTS, or AMPS function for display on both the digital and analog meter readouts. The full scale value of the meters is determined by the function selected.

- In the AMPS position, the meters display the plasma tube current in amps. Full scale is 100 A.
- In the VOLTS position, the meters display the plasma tube voltage in volts. Full scale is 1000 V.
- In the WATTS position, the meters display the optical output power in watts. Full scale is determined by the selected range.

RANGE switches—step up (▲) or step down (▼) the power range selection. One of the five indicators listed below glows to display the active range.

Indicator	Meter Full Scale
30	31.6 W
10	10.0 W
3.0	3.16 W
1.0	1.0 W
0.3	0.316 W

DANGER

Changing the power range when the system is in power mode will result in a change in the output power of the laser. Example: the laser is operating at 200 mW in power mode, and the selected power range is 0.3 W. Changing the power range to the 30 W range causes the output power to rise to full output.

After main power is turned on, the system must warm up for 5 min before the power readings can be considered accurate. The photocell in the light pick-off housing is temperature regulated and requires a 5 min warmup. The power meter/photocell circuit remains stabilized as long as the main power is on. Turning the key switch on or off does not affect the temperature.

Internal DIP Switch Settings

A 6-switch DIP switch (SW1) inside the Model 2470 remote control module allows the turn-on configuration to be changed. The factory configuration is with the following settings active at turn-on: current mode, 0.3 W range, remote control, and the remote/computer switch disabled. To change this configuration, set the switches according to Table 4-1.

Changing the Settings on SW1

1. Turn off main power to the system.
2. Remove the screws (2) at the top and bottom of the back side of the remote module.
3. Lift the control panel assembly out of the base enclosure about 2 in. so you have access to SW1.
4. Set the switches on SW1 according to Table 4-1, then reverse steps 1, 2, and 3 to reassemble the module.

Table 4–1: DIP Switch SW1 Function Table							
Function		**DIP Switch**					
		1	**2**	**3**	**4**	**5**	**6**
Range	0.3W	On	Off	Off			
	1.0W	Off	On	Off			
	3.0W	On	On	Off			
	10W	Off	Off	On			
	30W	On	Off	On			
Mode	Power				Off		
	Current				On		
Control Source	Remote					Off	
	Computer					On	
Remote/ Computer Switch	Disabled						Off
	Enabled						On
Factory Setting		On	Off	Off	On	Off	Off

Table 4–1: DIPswitch SW1 Function Settings

REMOTE/COMPUTER Switch

The REMOTE/COMPUTER switch toggles the control source for the system between the Model 2470 remote module and a computer. The factory setting for this switch is to have it disabled so that only the remote position can be selected. If you plan to operate the system under computer control and want to be able to switch between remote and computer control, you must enable the switch by setting SW1-switch 6 to ON. We recommend that you enable this switch only if you have to change between remote and computer control.

> *NOTE*
>
> If the REMOTE/COMPUTER switch is enabled, and you attempt to change the control source from remote to computer, the laser will shut off unless a computer is connected to the power supply and the Model 2180 computer interface board has been initialized. Refer to Chapter 6 for information on computer control.

If you plan to operate under computer control only, set SW1-switch 5 to ON and SW1-switch 6 to OFF. Under this configuration the system will always turn on with computer control active and the REMOTE/COMPUTER switch disabled.

Remote Connector Pin Assignments

Table 4-2 describes the function of each pin of the REMOTE connector located on the connector panel of the Model 2570 power supply. All logic inputs are optically coupled and require driving logic that can sink 10 mA with a "logic low" voltage of less than 0.8 V.

Table 4–2: Remote Connector Pin Assignments

Pin	Name	Type	Description
1	GND	Output	Model 2570 power supply digital ground.
2	GND	Output	Model 2570 power supply digital ground.
3	Computer /Remote	Input	Selects control source. When this input is pulled low, control signals on input pins 4, 5, 6, 7, 8, 19, and 36 are enabled. When the input is inactive (high), signals on pins 4, 5, 6, 7, 8, 19, and 36 are ignored, and control inputs are taken from a computer connected to the power supply through the RS-232-C or IEEE 488 interfaces. The computer interface is an optional accessory.
4	Pre0	Input	One of three inputs used to select power range. Input signals on pins 4, 5, and 7 together select the power range according to the following table:

Pre2 (Pin 7)	**Pre1 (Pin 5)**	**Pre0 (Pin 4)**	**Power Range**
Low	Low	Low	0.3 W
Low	Low	High	0.3 W
Low	High	Low	1.0 W
Low	High	High	3.0 W
High	Low	Low	10 W
High	Low	High	30 W
High	High	Low	0.3 W
High	High	High	0.3 W

Pin	Name	Type	Description
5	Pre1	Input	One of the three inputs used to select power range (see pin 4 description).
6	Control Mode	Input	Selects feedback mode. When this input is pulled low, power mode is selected; when it is inactive (high), current mode is selected.
7	Pre2	Input	One of the three inputs used to select power range. (see pin 4 description).
8	Plasma On/Off	Input	The main laser on/off control. Pulling this input low closes the power contactor and begins to warm up the tube cathode. The laser will light after about 15 sec.

Table 4-2: Remote Connector Pin Assignments *(cont.)*

Pin	Name	Type	Description
9	AUX Interlock Open	Output	When the interlock is open, the output is inactive (high); if it is closed, the output is pulled low.
10	High Water Temp	Output	When the head outlet water temperature exceeds 78 deg C (172 deg F), the output is inactive (high); otherwise the output is pulled low.
11	Head Cover Interlock Open	Output	When the cover interlock switch in the head is open, the output is inactive (high); if it is closed, the output is pulled low.
12	Low Water Flow	Output	When the water flow rate through the head is less than 5 gpm, the output is inactive (high); otherwise, the output is pulled low.
13	Regulator Fault	Output	Under normal operating conditions, the output is pulled low. However, when the laser cannot be turned on because of faulty operation of the head or power supply, the output is inactive (high). Possible fault conditions are: current to the laser head had exceeded the maximum safe operating limit of 65 A; the plasma tube has run out of gas and cannot be filled; or, the power supply is defective.
14	Voltage Monitor	Output	This is a 0 to 5 V analog signal representing 0 to 1000 V plasma tube voltage.
15	Current Monitor	Output	This is a 0 to 5 V analog signal representing 0 to 100 A plasma tube current.
16	Power Monitor	Output	This is a 0 to 5 V analog signal representing optical output power from 0 W to a full scale value determined by the active power range (see following table).

Power Monitor (0 to 5 V)	Power Range
0 to .316 Watts	0.3 W
0 to 1.0 Watts	1.0 W
0 to 3.16 Watts	3.0 W
0 to 10.0 Watts	10 W
0 to 31.6 Watts	30 W

Table 4–2: Remote Connector Pin Assignments *(cont.)*

Pin	Name	Type	Description
17	Buffered +5VREF	Output	+5 V reference (10 mA maximum).
18	GND	Output	Model 2570 power supply digital ground.
19	Current Control	Input	This is a 0 to +5 V full scale command signal that selects the desired plasma tube current when the laser is operated in the current mode (pin 6 inactive) and under remote control (pin 3 low). The input may be used to manually select the current setpoint when it is connected to the wiper arm of a 10K Ω potentiometer. The other two terminals of the potentiometer should be connected to Buffered +5VREF (pin 17) and CMD CMN (pin 37). The full scale value of the command signal represents 100 A plasma tube current.
20	Premon0	Output	One of the three outputs that monitor the power range selection. Output signals on pins 20, 21, and 26 together indicate the power range according to the following table: **Premon2 (Pin 26) / Premon1 (Pin 21) / Premon0 (Pin 20) / Power Range** Low / Low / High / 0.3 W Low / High / Low / 1.0 W Low / High / High / 3.0 W High / Low / Low / 10 W High / Low / High / 30 W
21	Premon1	Output	One of the three outputs that monitor the power range selection (see pin 20 description).
22	Digital Input Common	Input	Current sources for optically coupled logic input signals on pins 3, 4, 5, 6, 7, and 8. Requires a +5 V pull-up at 50 mA, which may be taken from pins 23, 24, or 27.
23	+5V	Output	+5 Vdc at 500 mA (maximum current available to combined output pins 23, 24, and 27).
24	+5V	Output	(See pin 23 description).
25			Not used

Table 4-2: Remote Connector Pin Assignments *(cont.)*

Pin	Name	Type	Description
26	Premon2	Output	One of three outputs that monitor the power range selection (see pin 20 description).
27	+5V	Output	(See pin 23 description).
28	+12V	Output	+12 Vdc at 50 mA (max).
29	-12V	Output	-12 Vdc at 50 mA (max).
30	Tube Fill Status	Output	When this output is inactive (high), low gas pressure is indicated, and the plasma tube is in need of a fill. If the automatic fill system is on, or, if the gas pressure is lower than the fill safety level, the fill system will be filling the tube while the output is high. When the output is repeatedly pulled high and low (1 Hz square wave), an empty gas reservoir is indicated, and the tube can no longer be operated. When the output is held constantly low, the tube is maintaining sufficient gas pressure.
31	Remote Emission Indicator	Output	When this output is pulled low, the laser is turned on and (following an initial fifteen second warmup delay) is capable of emitting light. If it is inactive (high), the laser is turned off.
32	P.S. Type	Output	This output is always pulled low.
33	Modemon	Output	This output monitors the control mode selection. When it is pulled low, power mode is selected. If it is inactive (high), current mode is selected.
34	Monitor Jack	Input	Signal input to the monitor jack located on the Model 2570 power supply connector panel.
35	REF GND	Output	Common reference return line for output signals Voltage Monitor (pin 14), Current Monitor (pin 15), Power Monitor (pin 16), Buffered +5VREF (pin 17), and for Monitor Jack (pin 34).

Table 4-2: Remote Connector Pin Assignments *(cont.)*

Pin	Name	Type	Description
36	Power Control	Input	This is a 0 to +5 V full scale command signal that selects the desired optical output power when the laser is operated in the power mode (pin 6 low) and under remote control (pin 3 low). The input may be used to manually select the power setpoint when it is connected to the wiper arm of a 10K Ω potentiometer. The other two terminals of the potentiometer should be connected to Buffered +5VREF (pin 17) and CMD CMN (pin 37). The full scale value of the command signal is determined by the active power range (see following table). **Power Control (0 to 5 V)** / **Power Range** 0 to .316 Watts — 0.3 W 0 to 1.0 Watts — 1.0 W 0 to 3.16 Watts — 3.0 W 0 to 10.0 Watts — 10 W 0 to 31.6 Watts — 30 W
37	CMD CMN	Input	Common reference return line for command signals Current Control (pin 19) and Power Control (pin 36).

Chapter 5 Operation

Power Supply Connectors and Indicators

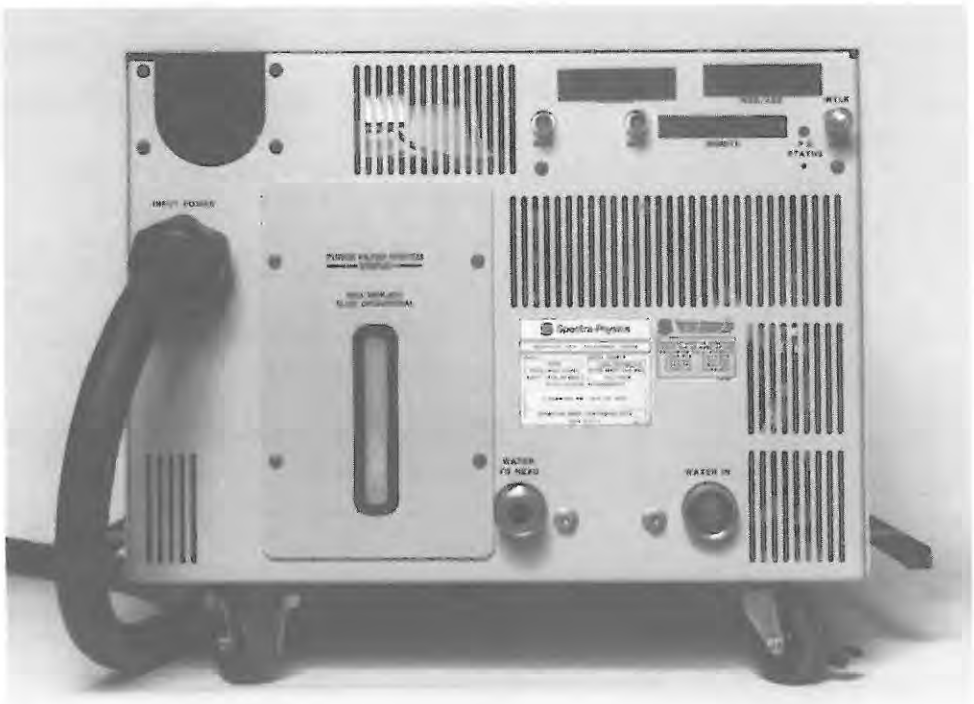


Figure 5–1: Model 2570 Power Supply Connector Panel

RS232C receptacle–accepts an RS232C connector when the system is operated by computer control.

IEEE/488 receptacle–accepts an IEEE/488 connector when the system is operated by computer control.

MODulation jack (BNC)–allows laser performance to be modulated externally. A 0 to ±5 V signal input at this connector will affect the laser at the rates shown in the following chart:

MODE Switch	RANGE Switch	Modulation Sensitivity
Current	n/a	20 A per V
Power	30 W	6.32 W per V
Power	10 W	2.0 W per V
Power	3.0 W	0.63 W per V
Power	1.0 W	0.2 W per V
Power	0.3 W	0.06 W per V

The total command signal to the power supply is the sum of the signals from the modulation connector and the active control knob (current or power). To illustrate, with the system in current mode and the current control knob set to 40 A, a ±0.5 V signal will vary the operating current from 30 to 50 A. The rise time between 20 and 55 A is < 20 ms; above 55 A the rise time is subject to the slew rate of the dynamic current limit. The frequency response range is 0 to 100 Hz. The input impedance is approximately 20 kΩ. The allowable input voltage range is ±5 V.

MONitor jack (BNC)–provides a 0 to 5 V signal that matches the active function on the remote control module.

Active Function	Range Selected	0-5 V (dc) Represents
AMPS	n/a	0-100 A
VOLTS	n/a	0-1000 V
WATTS	30 W	0-31.6 W
WATTS	10 W	0-10 W
WATTS	3.0 W	0-3.16 W
WATTS	1.0 W	0-1 W
WATTS	0.3 W	0-0.316 W

REMOTE receptacle–connects the Model 2470 remote control module to the power supply.

P.S. STATUS indicator–glows when the low voltage control power supply is operating correctly.

AUX INTLK–its contacts must be shorted together before the laser will operate. A jumper plug is installed at the factory. It can be replaced by auxiliary safety equipment such as a door switch that shuts off the laser.

PURGE FILTER SYSTEM STATUS–shows the condition of the purge filter dessicant. When the granules in the dessicant turn pink or red, the filter should be replaced, see "Maintenance: Changing the Purge Filter."

Laser Head Controls and Indicators

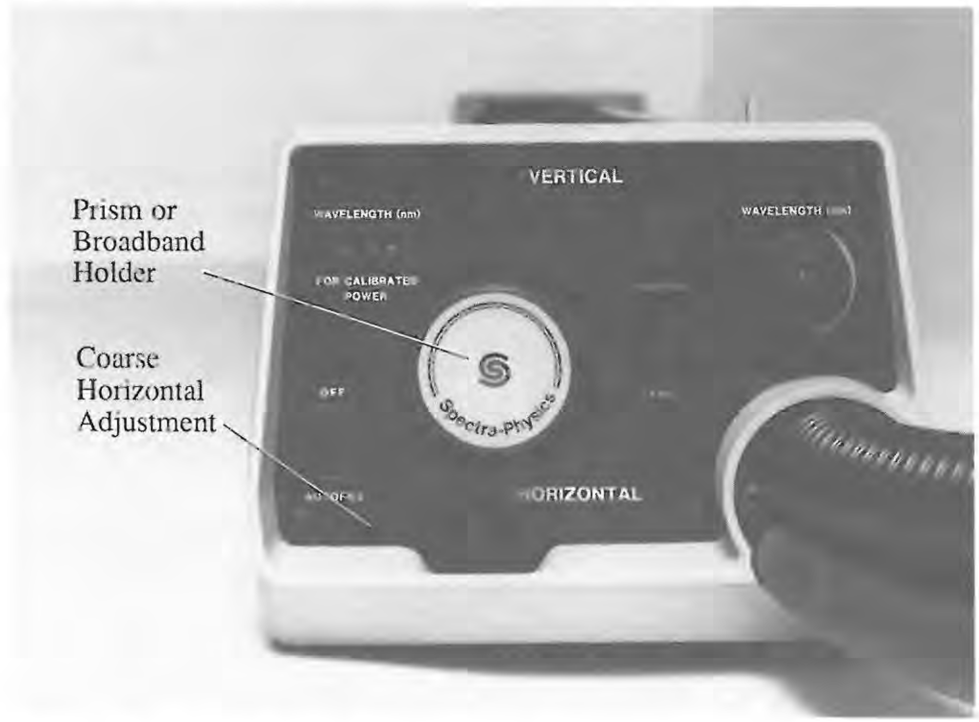


Figure 5–2: Model 2040 Laser Head Control Panel

COARSE VERTICAL **adjustment**–changes the vertical alignment of the high reflector allowing rapid adjustment for optimum broadband performance. During single–line operation it provides a quick scan of individual laser lines. This knob also moves the WAVELENGTH indicator to the corresponding wavelength in nanometers.

FINE VERTICAL **adjustment**–moves the high reflector at 1/30th the rate of the coarse adjustment. Used for fine tuning both broadband and single–line performance. The pointer in the outer ring of the WAVELENGTH dial indicates the position of fine adjust within the range between two indicating lines.

Coarse horizontal adjustment–changes the horizontal alignment of the high reflector allowing rapid adjustment for optimum performance. It is accessible with a hex driver through a hole in the control panel at the left-hand side of the fine adjust knob.

Fine HORIZONTAL adjustment–moves the high reflector at 1/30th the rate of the coarse adjustment. Used for fine tuning both broadband and single-line performance.

WAVELENGTH indicator–functions in two sections:

- The inner dial, marked with wavelengths in nanometers, moves with both of the VERTICAL adjustments and shows the approximate wavelength at the white line.
- The outer dial, labeled RANGE FINE ADJUST, moves with the VERTICAL FINE adjustment; the pointer shows the position within the fine adjust range between the two indicating lines.

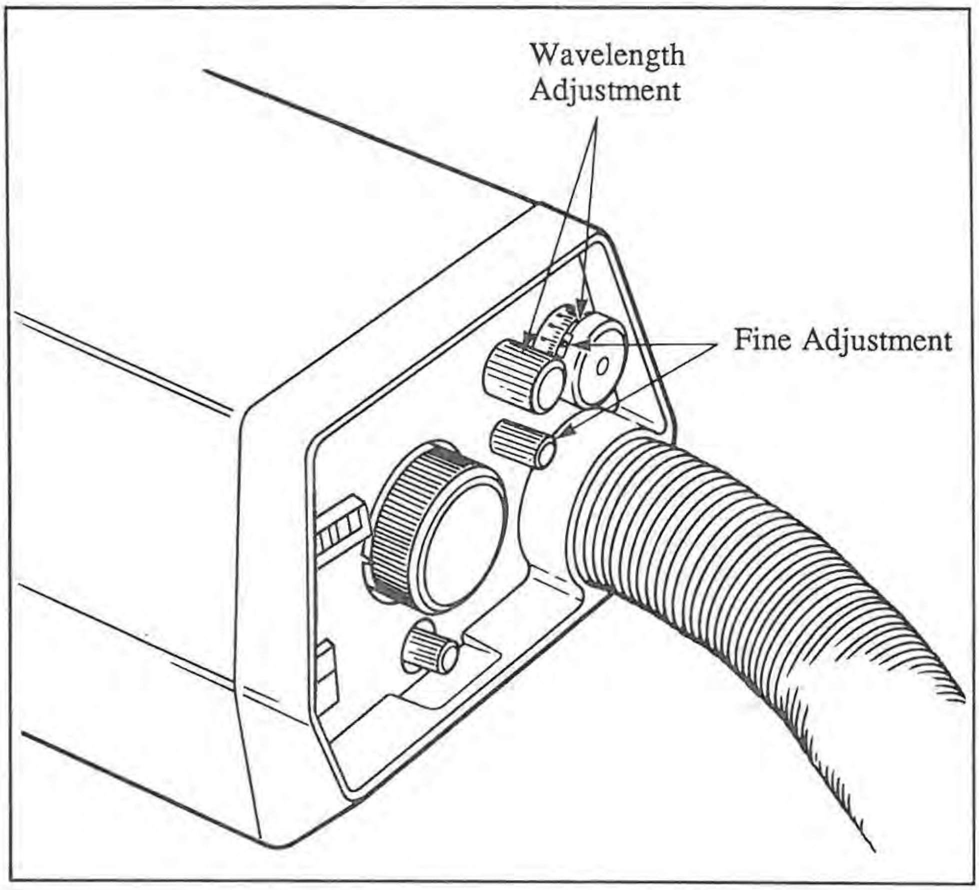


Figure 5-3: Wavelength Indicator

WAVELENGTH CALIBRATION switches–must be set to match the operating wavelength so the remote module power meter readings will be calibrated. When using broadband visible optics, set the switch to 500. When using broadband UV optics, set the switch to 350. When using deep UV optics, set the switch to 290. For wavelengths between 1000 and 1090 nm, ignore the 1 in the thousandth place. For example, the setting for 1090 nm is 090.

The power meter readings are subject to the following accuracy ranges depending on wavelength:

275 to 799 nm - single line	±10% maximum ±5% typical
275 to 799 nm - broadband	±15% maximum ±10% typical
800 to 1090 nm - single line	±20% maximum ±15% typical

When switching from one power range to another, for example going from 3W to 10W setting, the power meter readings are subject to these accuracy ranges: ±4% maximum, ±1% typical.

AUTOFILL pushbutton switch–toggles the autofill system between the "on" condition (light off) and the "off" condition (light on.) In the on condition, the autofill system fills the tube when the tube voltage drops below the fill threshold level.

In the off condition, the autofill system fills the tube when the tube voltage drops below the fill safety level (4% below fill threshold.) The autofill system always defaults to the on condition when main power to the laser system is turned on.

Laser Head Hatch Cover

The laser head is equipped with a hinged hatch cover to allow access to the interior of the laser head at the high reflector end. Lifting this cover opens the laser head cover interlock, which would shut off the laser if it was running.

Starting the Laser

WARNING

The output beam of this laser is a safety and fire hazard. Avoid viewing the beam directly or blocking it with clothing or parts of the body.

1. Place a beam block or an external power meter in the beam path and close the shutter.

2. Check the ac power line voltage; it should be 480 V ± 8%. Extended operation near the limits of this range is not recommended.
3. Assure yourself that the green lead of the power cable is connected to earth ground.
4. Turn on the cooling water supply.
5. Turn on the main power. The P.S. STATUS indicator on the power supply connector panel should turn on.
6. On the remote module, select the current mode position.
7. Move the current control knob fully counterclockwise, its minimum setting.
8. Test the flow switch: turn off the water supply; the FLOW indicator should turn on within a few seconds. If it does not turn on, contact your Spectra-Physics service representative.
9. Turn on the water supply.
10. Turn the key switch one-quarter turn clockwise. The emission indicator turns on and after a 15 sec delay, the start circuit provides a pulse to initiate the plasma discharge.
11. Open the shutter; the laser beam will emerge from the output end of the laser head.
12. Allow the laser to warm up for at least 10 min in the current mode; then turn up the current gradually to your required level in either current control or light control mode.

NOTE

The laser turns on in whichever mode (current or power) is active and at the current or power level set by the active control knob. If the control knob is set to a level above 55 A, the current rise will be subject to the dynamic current limit described previously.

Low Power Operation in Power Mode

In the power control mode, the range of control is from about 1/20 of the power meter full-scale setting up to the maximum of the full-scale setting. The power supply provides effective regulation from about 50 mW up to full output power, although best signal-to noise ratios are at settings above 1/3 of power meter full scale. However, certain high-gain lines such as 488 nm, will not drop as low as 50 mW before discharge ceases. An external attenuator is recommended where stable output of less than 50 mW is required of such lines.

Adjusting for Maximum Output Power

Assuming the laser has been allowed to warm up properly, misalignment of the rear mirror mount is the most frequent cause of low output power. The beam must strike the mirror at right angles for optimum performance. If the mirror is misaligned on either the horizontal or vertical plane, or both, laser output will suffer.

Monitor the output power with the power meter; the power supply must be in the current control mode.

The mirror mount is designed so both planes can be independently adjusted. Use the vertical and horizontal coarse adjustments for the following procedure; insert a #23 (3/32 in.) driver in the horizontal coarse adjustment.

Turn one control while observing the change in output power. If the power increases, continue to turn the control in the same direction. If the power declines, turn the control in the opposite direction.

Achieve maximum power with one control before moving to the other one, then adjust the other control in the same way. The adjustments may interact with each other, so you will need to repeat the procedure, first with one control, then with the other, until the highest possible output power is achieved.

If the unit stops lasing while you are turning one of the controls, turn it in the opposite direction until lasing is restored. Leave the other control alone until you get the unit lasing again.

Only adjust the high reflector to achieve maximum power. The curved output coupler should remain stationary under normal operating conditions. If its alignment is disturbed, realignment may be time consuming and tedious. If, after adjusting the high reflector, the output performance remains below specification, clean the mirrors and plasma tube windows. If this fails to restore power, the output coupler or plasma tube may be misaligned; refer to "Service and Repair" for troubleshooting and alignment details.

Wavelength Selection

For single–line operation the rear optics assembly contains a prism and a flat high reflector. The prism disperses the laser beam, bending individual lines according to their wavelength. A line will oscillate if its angle of refraction through the prism matches the vertical rotation angle of the prism. As you turn the vertical adjusting screw of the high reflector mount, the angle at which the beam strikes the prism will change, and with it the wavelength of the oscillating line.

The wavelength indicator on the laser head will indicate the approximate wavelength in nanometers. The lines can also be identified by their relative power, a comparison of which is found in the output power specifications. Positive identification of weaker lines requires a spectroscope.

Using the Shutter

The Model 2040 laser head is equipped with a shutter that blocks the intracavity beam. Switch the power supply to the current control mode before closing the shutter. If the power supply is left in the power mode when the shutter is closed, the power control circuit will increase plasma tube current to maximum. Prolonged operation at maximum current may reduce plasma tube life.

Adjusting the Aperture for TEM_{00} Output

Well defined variations in the spatial distribution of the electromagnetic field perpendicular to the direction of travel of the beam are called Transverse Electromagnetic, or TEM, modes. These variations determine, in part, the power distribution across the beam.

Most laser applications require a TEM_{00} beam, which appears as a round spot that is brighter in the center than it is on its edges (Figure 5–4). Other modes have different irradiance contours and are identified by the number of nulls in the irradiance distribution. The mode pattern for a given laser is a function of wavelength and can be affected by the size of the aperture, scratches on the mirrors, or dust on the optical surfaces.

The aperture control allows adjustment for true single–mode (TEM_{00}) output over a wide range of wavelengths. The aperture may also be used to reduce output power or, if TEM_{00} performance is not required, to increase it. The aperture selection to achieve TEM_{00} power may change as the plasma tube ages.

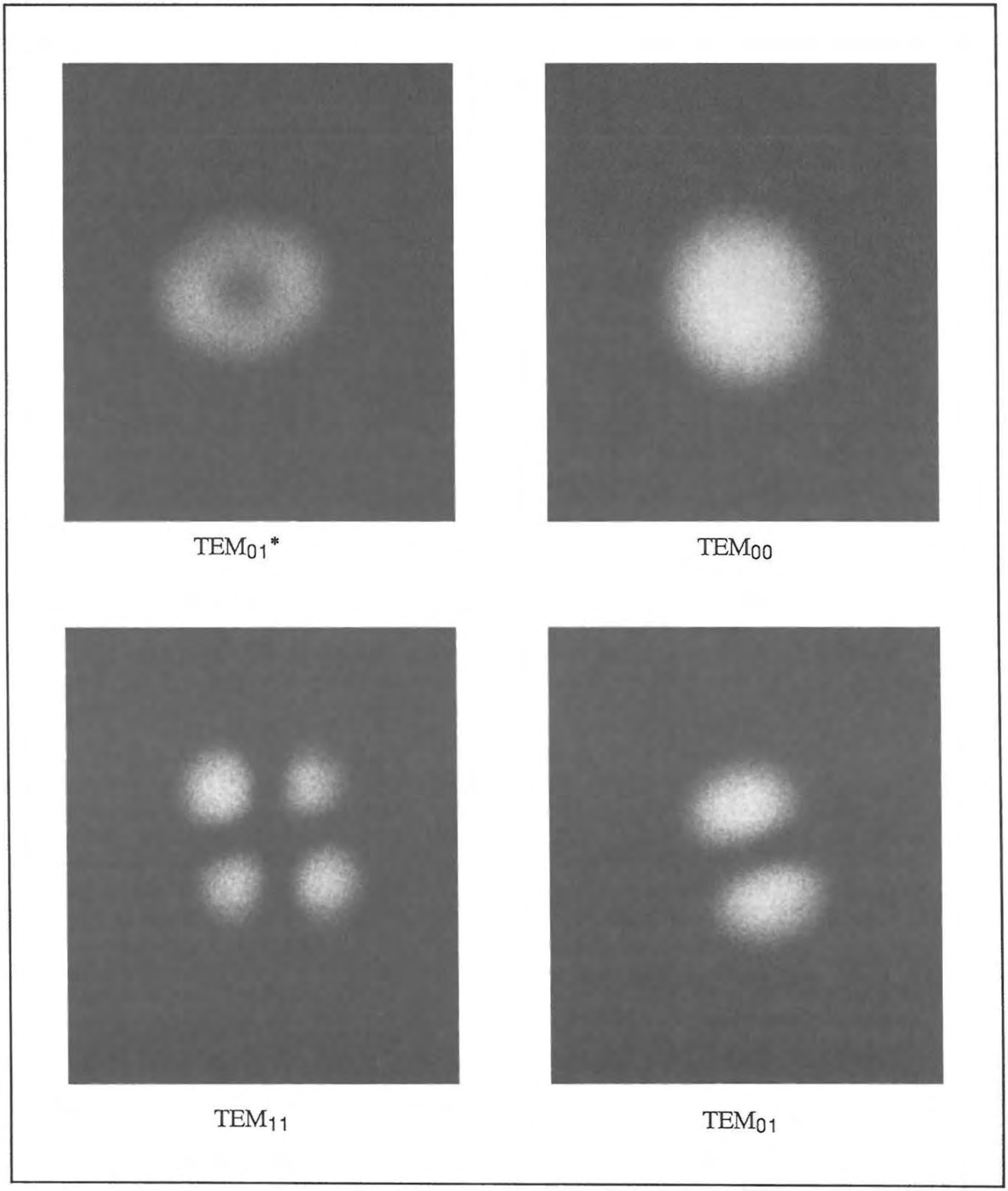


Figure 5–4: Transverse Modes

You may find it difficult to identify the mode of a beam by direct observation; however, lenses can be used to expand the beam, making observation of irradiance distribution easier.

DANGER
The Model 2040 is a Class IV laser whose beam is, by definition, a safety hazard. Even reflected beams can be dangerous. Use a neutral density attenuator for mode observations and adjustments. Make sure the beam only strikes low-reflectance surfaces.

Place a positive lens (focal length about 1.5 cm) in the beam path and observe the beam, expanded to about 0.5 m, on a wall or screen. Multimode conditions appear as complex variations in the pattern. As the aperture closes, the multimode patterns will shrink in overall diameter, and the rapid intensity variations across the beam will disappear. TEM^*_{01} – the "donut" mode – may appear; then, as the aperture tightens further, the TEM_{00} condition is established.

Gas Autofill System Operation

The gas autofill system continuously monitors the tube voltage, which is directly related to gas pressure and plasma tube current. The tube is automatically filled to either the fill threshold level (when the autofill switch is on), or the fill safety level (when the autofill switch is off.) The autofill system always defaults to the on condition when main power to the laser system is turned on. The fill circuit has a built in 15 min delay to allow the gas pressure to stabilize after the tube is turned on. The tube can not be filled for the first 15 min of operation. The fill threshold level for the Model 2040 and 2045 is 553 V ±5 V at 65 A, and 395 V ±5 V at 30 A. A current-to-voltage ratio determines the value of the fill threshold level at any current. The power may change by 1 to 2% after the fill cycle is completed.

Operation with Autofill Turned On

In the automatic fill mode, the system senses when the tube voltage drops below the fill threshold level. After a 15 min delay, the FILL indicator on the remote module turns on and the fill circuit initiates the fill sequence. The fill system then fills the tube until it reaches the fill threshold level.

Operation with Autofill Turned Off

In this condition, the light above the switch will be on. The autofill system senses when the tube voltage drops below the fill safety level, which is 4% below the fill threshold value. After a 15 min

delay, the FILL indicator turns on and the autofill system fills the tube back to the fill safety value.

Changing Optics

WARNING
The optics are fragile and can be damaged if dropped. Work over a clean, dust-free, soft surface.

The Model 2040 comes equipped with a set of mirrors designed for optimum performance within the wavelength range specified at the time of purchase. Additional sets of optics can be obtained from Spectra-Physics.

The mirror mount features a bayonet receptacle for mirror holders, providing quick access and precise replacement for high performance without undue adjustment. The output-end assembly holds the output coupler, a thin-film mirror that is coated to allow a few percent transmission of desired wavelengths. The prism and broadband high reflector assemblies hold flat mirrors coated for high reflectance of desired wavelengths.

Your laser will usually operate at full power after changing optics and peaking the vertical and horizontal controls, although several minutes may be required until the purge system can completely clean up the intracavity air. Always align your laser for maximum output power before removing any of its optics. Remove and replace them one at a time, and repeak the power upon replacement, adjusting only the mirror that was removed. If a significant power loss occurs, try removing, cleaning, and installing the mirror again.

When changing output couplers, hold the output assembly vertical with the mirror on top. Use finger cots to protect the mirror during removal and replacement. A Spectra-Physics part number and an arrow appear on the edge of each mirror. Insert the mirror so the arrow points toward the laser cavity; Table 5-1 identifies available optics.

When changing from the broadband holder to the prism holder, the unit will lase at 488 nm. To return to the broadband, first peak the prism at 488 nm, then remove the prism holder and install the broadband holder.

The output and broadband mirror holders and prism assembly are designed to lock in precise alignment. If you notice that a mirror appears tilted in its holder, its alignment lock is disengaged. Try turning the mirror and its spring-loaded cup until the locking mechanism snaps back in place. You won't be able to turn the mirror and cup further, and the coated surface will be perpendicular to the long axis of the mirror holder. If the mirrors are clean and locked in alignment, but the output power remains low, refer to "Service and Repair."

Under normal operating conditions the output coupler should not need adjustment after a mirror change. Avoid tampering with output mirror controls unless you are certain that it is misaligned; re-alignment can be time consuming and tedious.

To reach the high reflector in the prism assembly (Figure 5-5), unscrew the knurled retaining ring and lift the assembly from its protective cup. A small screw holds the mirror retaining spring in place; remove it and invert the assembly, dropping the mirror onto a soft surface. Reverse the sequence to replace the mirror.

Figure 5-5: Model 2040 Single-line Prism Assembly

Figure 5-6: Model 2040 Optics Assemblies

Table 5-1: Model 2040 Optics Selection

Laser Model[1]	Wavelength (nm)	Output Coupler	Broadband/ Prism HR
2040– 15, 20, 25	457.9–514.5 333.6–363.8	G3873-016 G3873-017[2]	G3802-009 G3802-028[2]
2045– 15, 20, 25	457.9–514.5 333.6–363.8	G3873-016 G3873-017	G3802-009 G3802-028 G0326-001[3]
	275.4–305.5	G3873–018	G3802-029 G0326-002[3]

1. *All optics are included with a standard model, except where noted.*
2. *These optics are optional and must be ordered in addition to the standard optics.*
3. *The use of these optics results in a larger mode and higher TEM_{00} power.*

Related Optics	Part Numbers
Output Mirror Holder	0428-5640
Beam Splitter	G0062-000
Prism Assembly	0428-6080
Prism	G0317-000
Broadband Holder	0428-5650

Etalons

- The Model 583 temperature stabilized etalon allows single frequency operation at low gain lines such as 457.9 nm.
- The Model 589 air-spaced etalon allows single frequency operation at 488.0 and 514.5 nm.

Model 2045 Operation in Deep UV (275 to 306 nm)

Because of strong absorption of these wavelengths by intracavity ozone, a nitrogen purge of the intracavity spaces is required. The purge nitrogen must be free of water, particulates, and organic contaminants.

Disconnect both the black and blue purge connectors inside the laser head near the high reflector endplate. Connect the nitrogen line to the black fitting and leave the blue fitting disconnected. The nitrogen flow rate should be about 0.23 l/min (14.04 in^3/min.)

Shutdown Procedure

1. Put the power supply in the current mode and turn down the current to minimum.
2. Turn the key switch one-quarter turn counter-clockwise to turn off the laser. Remove the key; don't leave the laser accessible to people who are untrained in laser safety or operation.
3. Wait about 2 min, then turn off the water supply and open the main circuit breaker.

Chapter 6 Model 2680 Computer Interface Board

Functional Overview

The Model 2570 power supply may optionally include the Model 2680 computer interface board. This board is designed especially for interfacing Spectra-Physics power supplies and other instruments to computers through either an RS-232-C or IEEE 488 interface. With this option the power supply can be operated from a computer or terminal control source.

To use the computer interface while the Model 2470 remote control module is connected to the power supply, the REMOTE/COMPUTER switch on the remote control must be set to COMPUTER. The remote control meter readings and status indicators will continue to monitor the system operation while the laser is operated under computer control.

NOTE
If all power range indicators on the remote control module are off when the REMOTE/COMPUTER switch is set to COMPUTER, then the computer interface board has not been initialized. Refer to "Interface Initialization" in this chapter for instructions.

Computer Control and Diagnostic Functions

The following control and diagnostic functions are available to the user when the power supply is operated under computer control:

Control Functions

- turn the plasma tube current on and off
- select either current or power control mode
- select either 0.3 W, 1.0 W, 3.0 W, 10.0 W, or 30.0 W power ranges
- regulate plasma current or optical output power

- turn the autofill system on or off

Diagnostic Functions

- monitor tube voltage, current, and optical output power
- monitor interlock, regulator, and tube fill status
- monitor power range selection, autofill board DIP switch status, and +5 V reference signal

Universal Interface Commands

The computer interface board is a "universal" data acquisition and control board used in several instruments made by Spectra-Physics. A general set of commands allows you to control and monitor selected digital and analog I/O lines of the computer interface board. Only five commands are needed to perform all control and monitoring functions in the power supply.

1. The CONFIGURE command activates the digital control outputs of the computer interface board.
2. The WRITE command turns the plasma tube current on or off, selects either current or power mode, activates one of five power ranges, and turns the autofill system on or off.
3. The READ command monitors interlock and regulator status and the autofill board DIP switch setting.
4. The SET command controls the setpoints for the current and optical output power.
5. The SAMPLE command measures the plasma tube voltage, current and optical output power, and monitors the power range selection, tube fill status, and the +5 V reference signals.

Power On Default State

When the power supply with the computer interface board is first turned on, digital control outputs of the interface board (plasma on/off, control mode, power range select, and autofill status) are all tri-stated, and the digital-to-analog converter outputs (current and power controls) are 0 V. While the control outputs are tri-stated, the power supply can be operated by a remote control panel connected to the power supply through the 37-pin REMOTE connector on the rear panel of the power supply.

Interface Initialization

The CONFIGURE command activates the digital control outputs of the computer interface board. Once configured, only a computer connected through the computer interface can operate the power supply; the 37-pin REMOTE connector is disabled.

Before any other commands are given, the digital control outputs must be set and configured with the following sequence of commands:

```
WRITE 6,8
WRITE 7,1
CONFIGURE 6, OUTPUT, NONCLOCKED
CONFIGURE 7, OUTPUT, NONCLOCKED
```

This initializes digital control outputs with plasma control off, and current mode selected.

IEEE 488 Interface

Operation

The IEEE 488 interface conforms to the ANSI/IEEE Standard 488–1978. The computer interface board is a talker–listener device and will execute data transfers from and to the interface bus when the IEEE 488 (GPIB) bus controller has addressed the interface board to talk or listen.

Command string transfers from the bus controller to the computer interface board need to be terminated by specially defined end-of-message characters; the GPIB END message is not required to terminate these messages. Refer to "Message Formats" in this chapter for more information regarding the end-of-message characters. The computer interface board, on the other hand, uses the END message to terminate all data transfers from the interface board to the bus controller.

Remote Reset

The computer interface board responds to the Device Clear (DCL) and Select Device Clear (SDC) GPIB bus messages. With either of these messages the bus controller can reset the computer interface board to the power on default state at any time.

A word of caution about the use of the DCL and SDC messages to reset the computer interface board: when the interface board resets, it takes about 100 msec to reinitialize before it is ready to receive commands from the bus controller. The bus controller may not send any messages to the interface board during this initialization period. Most computer programs will need to execute some delay following the transmission of the DCL and SDC messages before sending another message to the interface board.

Serial Poll Status Byte

The computer interface board also responds to the Serial Poll Enable (SPE) bus message. The computer interface board maintains a status byte that stores the version number of the firmware, and indicates the execution status of the last command the interface board received from the IEEE 488 bus controller. The bus controller can read this status byte by sending the SPE bus message to the interface board. Typically, the IEEE 488 bus controller performs a serial poll of the computer interface board by executing a single statement, similar to this BASIC language statement of the HP9836 computer:

```
Uib_Status = SPOLL(725)
```

The status byte definition is shown in the the following diagram.

Most Significant Bit							Least Significant Bit
7	6	5	4	3	2	1	0
0	0	Firmware Version			Command Error	Data Ready	Operation Complete

Figure 6–1: Diagram of the Serial Poll Status Byte indicating the function of each bit.

Bit 0 is set whenever the interface board finishes execution of a command.

Bit 1 is set when the interface board has completed execution of the SAMPLE or READ commands, and response data is ready for output to the bus controller. It is reset when the interface has finished sending the response to the controller.

Bit 2 is set when an error is detected in the command line and the interface board has aborted command execution.

Bits 3, 4, and 5 indicate the firmware version installed on the interface board. The version number is represented as a three bit binary number of which bit 5 of the status byte is the most significant bit.

Bits 6 and 7 are always zero.

SW2 DIP Switch Setting

The IEEE 488 interface is simple to configure. You only need to select a device address for the interface board that is different from all other addresses of devices attached to the IEEE 488 interface bus. DIP switch SW2 on the computer interface board sets an address for the board. Any address from 0 to 31 may be selected. The factory setting is 25. The following diagram describes the use of DIP switch SW2.

Table 6–1: SW2 DIP switch settings for selecting IEEE 488 device address.

Switch Number	1	2	3	4	5
Bit Weight	16	8	4	2	1
Factory Setting (25)	On (16)	On (8)	Off	Off	On (1)

RS-232-C Interface

Operation

The RS-232-C interface standard classifies serial I/O devices as either data terminal equipment (DTE) or data communications equipment (DCE). The standard identifies the pin numbers of the interface connector used for various data and control lines in each type equipment. The standard does not define the exact function of all signals used by various manufacturers of serial I/O devices. As a result there is no guarantee that two devices can communicate with each other until all optional hardware and character format settings have been configured to match the requirements of each device.

The serial interface of the computer interface board is an RS-232-C compatible interface configured to emulate DCE equipment. Signal inputs and outputs of the serial interface are likely to be compatible with most computers and terminals configured as DTE equipment. If the computer interface board is connected to another DCE device, an interface cable adapter that crosses the data and control signal pairs is usually all that is needed to make the two devices compatible.

The following diagram shows the interface signals used and their interconnections using a standard RS-232-C cable. The data link signals are named relative to the data terminal device.

Terminal (DTE)		RS-232-C Link	Computer Interface Board (DCE)	
TXD	(2)	◄----Transmitted Data------►	(2)	RXD
RXD	(3)	◄----Received Data---------►	(3)	TXD
RTS	(4)	◄----Request To Send-------►	(4)	CTS
CTS	(5)	◄----Clear To Send---------►	(5)	RTS
DSR	(6)	◄--- Data Set Ready--------►	(6)	DTR
DCD	(8)	◄---- Data Carrier Detect ---►	(8)	DCD
DTR	(20)	◄---- Data Terminal Ready ---►	(20)	DSR
	(7)	◄----Signal Ground---------►	(7)	
	(1)	◄----Protective Ground------►	(1)	

Figure 6-2: Standard RS-232-C Interconnections

Data Transfer and Handshaking

The RS-232-C serial interface operates in the full duplex mode: data may be sent and received simultaneously. To synchronize data transmissions with the RS-232-C controller, the interface board implements a simple hardware handshaking protocol, monitoring and controlling the interface signals in the manner described below. Interface signals are named relative to the data terminal device.

Data Terminal Ready and Request To Send–computer interface board checks both of these lines when it has response data to send to the RS-232-C controller. It sends data only when both signals are turned on.

Data Set Ready, Clear To Send and Data Carrier Detect–the computer interface board keeps these lines turned on at all times. It is always ready to receive commands from the RS-232-C controller.

SW1 DIP Switch Setting

The computer interface board and the RS-232-C controller must both be configured to send and receive data at the same rate. DIP switch SW1 on the interface board selects one of several possible bit transmission (BAUD) rates. The factory setting is 4800 baud.

Switches five through eight on SW1 select the baud rate. The following table shows the settings for the available rates.

Table 6-2: SW1 Baud Rate Settings

Switch Number	Switch Position								
5	Off	Off	Off	Off	Off	Off	Off	Off	On
6	Off	Off	Off	Off	On	On	On	On	Off
7	Off	Off	On	On	Off	Off	On	On	Off
8	Off	On	Off	On	Off	On	Off	On	Off
Baud Rate	75	110	150	300	600	1200	2400	4800	9600

There are three character format settings that must also be configured to match in the two communications devices: character length, parity, and stop bit. SW1 is used to make these settings. The factory setting of SW1 selects eight-bit character length, parity odd and disabled, and two stop bits.

Table 6-3: SW1 Mode Select Settings

Switch Number	Switch Position	Condition	Switch Position	Condition
1	Off	Parity Disabled	On	Parity Enabled
2	Off	Odd Parity	On	Even Parity
3	Off	One Stop Bit	On	Two Stop Bits
4	Off	Seven Bits Per Character	On	Eight Bits Per Character

SW3 DIP Switch Setting

DIP switch SW3 on the computer interface board can be used to force the DATA TERMINAL READY and REQUEST TO SEND signals to an "on" condition. This may be necessary because some computers or terminals may not control these signals as we described previously. Both signals must be on to enable communications between the interface board and the RS-232-C controller. To force the DATA TERMINAL READY or REQUEST TO SEND line to an "on" condition, set the DTR or RTS switch of DIP switch SW3 to the "on" position.

Message Formats

Command Format

A command is a string of ASCII characters that the computer or terminal control source sends to the computer interface board. A command consists of a command word and may also include one to three additional data or keyword elements. A command may take one of the following forms:

<command word>
<command word> <data>
<command word> <data> <data>
<command word> <data> <keyword> <keyword>

A command also includes delimitation characters that separate elements in the command, and terminate each command. The comma and line feed characters are used for this purpose. These two delimiters are equivalent and may be used interchangeably, as these examples show:

<command word>, <data> <LF> <data> <LF>
<command word> <data>, <data>,

Notice that the delimiter between the command word element and the next element following it may be omitted.

Space characters and all nonprintable characters, except the line feed character, are ignored. Consecutive comma or line feed delimiters in a message are interpreted as a single delimiter.

The interface board recognizes the following command strings; they demonstrate the use of delimiters and optional spaces:

SET 1, 127<LF>
SET,2,255,
WRITE4,1001B,WRITE5,0110B<LF>

The use of comma or line feed characters as delimiters permits simple message formatting and entry from either a terminal or computer program, as these examples demonstrate:

Enter from terminal:

SET 1,127 <CR> <LF>

or execute program statements:

```
10 A$ = "SET"
20 B = 1
30 C = 127
40 OUTPUT A$,B,C
```

Command words and keywords may contain either upper or lower case alpha characters.

Command words and keywords may be abbreviated, but they must include enough letters to make the word unique. If the entire word is spelled out, or to the extent that it is abbreviated, it must be spelled correctly.

Command Word	Shortest Abbreviated Form Acceptable
CONFIGURE	CON
READ	REA
SAMPLE	SAM
SET	SET
WRITE	WRI
Keyword	
CLOCKED	CLO
INPUT	INP
NONCLOCKED	NON
OUTPUT	OUT

Numeric decimal data must be a floating point number from 0 to 255. Only the integer portion of the number is evaluated.

An input error occurs if any part of the command is invalid, such as a misspelled command word or keyword, a data value out of range, or an incorrect number of elements in the command. When an input error is detected, the interface board aborts command processing until it receives a new command.

Response Format

The computer interface board sends a response to the computer or terminal control source following execution of the READ and SAMPLE commands. A response is a string of ASCII characters terminated by the carriage return and line feed characters:

<response> <CR> <LF>

When the control source for the computer interface board is an IEEE 488 bus controller, the interface board also sends the GPIB END message to terminate transmission to the bus controller.

Commands

CONFIGURE p, <keyword>, <keyword>

p = port number (4, 5, 6, or 7)

keyword: INPUT, OUTPUT, CLOCKED, or NONCLOCKED

This command configures the specified port of the digital I/O circuit on the computer interface board as a clocked or nonclocked input or output port.

When NONCLOCKED is specified, digital patterns written to an output port are transferred immediately to the I/O connector pins. Likewise, input signals at the I/O connector pins are transferred immediately to port inputs to be read.

When CLOCKED is specified, the STROBE command must be executed in order to transfer digital patterns previously written to an output port to the I/O connector pins. Similarly, before a digital pattern can be read in through an input port, the STROBE command must be executed to transfer signal data from the I/O connector pins to the input port.

The CONFIGURE command must include the INPUT or OUTPUT keyword and the CLOCKED or NONCLOCKED keyword.

Each new CONFIGURE command executed to configure a particular port overrides the last CONFIGURE command executed for the port, and has no effect on the configuration of the other ports.

Normally, a port will be in either an output (write) or input (read) mode. If during the course of operation a port is reconfigured from an output port to an input port, the first read following a write should be ignored; all following reads are valid. A read operation leaves the port in a high impedance state.

Example commands:

CONFIGURE 4, INPUT, NONCLOCKED

CONFIGURE 5, CLOCKED, OUTPUT

READ p

p = port (4, 5, 6, or 7)

Directs the computer interface board to input the status of the specified port and to send a response giving the status of the four lines of the port. The response is a decimal number from 0 to 15.

To read the status of the TTL I/O lines of the interface board:

- the port must already be configured as an input.
- the first read following a write should be ignored (see CONFIGURE command description).
- the READ command is executed to input the status of four of the sixteen lines:

Port Specifier	Lines Input
4	DIG40 - DIG43
5	DIG50 - DIG53
6	DIG60 - DIG63
7	DIG70 - DIG73

The status read from a TTL input line is 0 when the signal is low, or 1 when the signal is high, and has the following bit weight in the decimal response:

DIGp3	8
DIGp2	4
DIGp1	2
DIGp0	1

Example command:

READ 7

Example response to the previous command:

12

SAMPLE a

a = analog input (1 to 8)

Directs the computer interface board to sample the specified analog input signal with the eight-bit analog-to-digital (A/D) converter, and to send a response giving the A/D conversion result. Analog inputs 1 through 8 are the interface board analog input signals A-IN1 through A-IN8. The response is a decimal number from 0 to 255.

The full scale input is 5.12 V, and each count of the conversion result is equivalent to 20 mV. The sampled voltage at the analog input is given by the equation:

$$V = 5.12\left(\frac{n}{256}\right)$$

Where V is the sampled analog input signal in volts, and n is the eight-bit A/D conversion result.

To prevent A/D rollover, clamping circuitry on the interface board limits the analog inputs to 5.08 V. Consequently, the highest conversion result that can be obtained for any analog input is 254.

Example command:

```
SAMPLE 1
```

Example response to the previous command:

```
127
```

Condition of analog input:

```
A-IN1 = +2.54 V
```

SET d,n

d = analog output (1 or 2)
n = D/A setting (0 to 255)

Sets the analog output of the specified eight-bit digital-to analog (D/A) converter to a voltage selected by the specified D/A setting. Analog output 1 is the computer interface board analog output signal A-OUT1, and analog output 2 is signal A-OUT2.

Jumpers on the interface board allow hardwire selection of one of two analog output ranges: 0 to +5.1 V and -5.1 to +5.1 V.

When the 0 to +5.1 V range is selected, the voltage at the analog output is given by the equation:

$$V = 5.1\left(\frac{n}{255}\right)$$

Where V is the analog output in volts, and n is the D/A converter setting value. Each count of the D/A setting value is equivalent to 20 mV of output voltage.

When the -5.1 to +5.1 V range is selected, the voltage at the analog output is given by the equation:

$$V = \left(10.2\left(\frac{n}{255}\right)\right) - 5.1$$

Where V is analog output in volts, and n is the D/A setting value. Each count of the D/A setting value is equivalent to 40 mV of output voltage.

Example command:

SET 1, 128

Condition of analog output:

A-OUT1 = +2.56 V (range: 0 to +5.1 V)
or
A-OUT1 = +0.02 V (range: -5.1 to +5.1 V)

WRITE p,b

p = port (4, 5, 6, or 7)
b = four-bit pattern (0 to 15) or (0000B to 1111B)

Writes a four-bit pattern to the specified port. The pattern may be specified as a binary or a decimal number. Binary numbers must have four digits and end with the suffix B. The most significant bit of the pattern is applied to the most significant output line of the port.

To write a bit pattern to the TTL I/O lines of the computer interface board:

- the port must already be configured as an output. If it is not yet configured as an output, the bit pattern written to the port will be applied to the TTL I/O lines after the port is configured as an output.
- the WRITE command is executed to output a pattern to four of the sixteen lines:

Port Specifier	Lines Input
4	DIG40 - DIG43
5	DIG50 - DIG53
6	DIG60 - DIG63
7	DIG70 - DIG73

An interface board TTL output line is set low when the pattern bit is 0, or high when the bit is 1.

Example commands:

WRITE 4, 1001B

WRITE 4, 9

Command Set Summary

The following computer interface board commands are used to execute the indicated control or measurement functions in the Model 2570 power supply.

CONFIGURE 6,OUT, NON	Configure digital port 6
CONFIGURE 7,OUT, NON	Configure digital port 7
READ 4	Input interlock status (key switch, cover, flow, temperature)
READ 5	Input interlock status (auxiliary, regulator fault) and autofill board switch setting
SAMPLE 1	Measure tube voltage
SAMPLE 2	Measure tube current
SAMPLE 3	Measure optical output power
SAMPLE 4	Measure +5 V reference
SAMPLE 5	Input tube fill status
SAMPLE 6	Input power range status
SAMPLE 7	Input power range status
SAMPLE 8	Input power range status
SET 1,n (n = 0 to 250)	Set current command voltage
SET 2,n (n = 0 to 250)	Set power command voltage
WRITE 6,8	Select current mode

WRITE 6,1	Select power mode, 0.3 W range
WRITE 6,2	Select power mode, 1.0 W range
WRITE 6,3	Select power mode, 3.0 W range
WRITE 6,4	Select power mode, 10 W range
WRITE 6,5	Select power mode, 30 W range
WRITE 7,1	Turn laser off
WRITE 7,0	Turn laser on, with autofill on
WRITE 7,8	Turn laser on, with autofill off

Status Port Definitions

A four-bit pattern is read from digital port 4 using the READ 4 command, and from digital port 5 using the READ 5 command. The most significant bit (msb) is shown.

Bit	**3 (msb)**	**2**	**1**	**0**
	Water Temp Interlock	Water Flow Interlock	Head Cover Interlock	Key Switch Interlock
	1=Normal 0=Temp >78°C	1=Flow OK 0=Flow < 5 gpm	1=Closed 0=Open	1=On 0=Off
Port 4 (READ 4)				

Bit	**3 (msb)**	**2**	**1**	**0**
	Autofill PCB		Regulator Interlock	Auxiliary Interlock
	DIPswitch 2	DIPswitch 1		
	1=Open 0=Closed		1=OK 0=Not OK	1=Closed 0=Open
Port 5 (READ 5)				

Control Port Definitions

A four-bit pattern is written to digital port 6 using the WRITE 6, b command, and to digital port 7 using the WRITE 7, b command. The pattern b must be specified as a decimal number from 0 to 15, or as a binary number from 0000B to 1111B.

Bit	3 (msb)	2	1	0	
	Control Mode	Power Range			Range
	1=Current 0=Power	0 0 0 1 1	0 1 1 0 0	1 0 1 0 1	0.3W 1.0W 3.0W 10W 30W
Port 6 (WRITE 6,b)					

Bit	3 (msb)	2	1	0
	Automatic Fill System	Not Used		Plasma
	1=Disabled 0=Enabled			1=Off 0=On
Port 7 (WRITE 7,b)				

Analog Input Definitions

The eight analog input signals are read using the SAMPLE a command.

Input Signal	Name	Description
A-IN1	Voltage Monitor	A 0 to 5 V signal representing 0 to 1000 V tube voltage
A-IN2	Current Monitor	A 0 to 5 V signal representing 0 to 100 A tube current
A-IN3	Power Monitor	A 0 to 5 V signal representing optical output power from 0 W to a full scale value determined by the active power range (see following table) **A-IN3** — **Power Range** 0 to 0.316 W — 0.3 W 0 to 1.0 W — 1.0 W 0 to 3.16 W — 3.0 W 0 to 10 W — 10 W 0 to 31.6 W — 30 W
A-IN4	+5 V Reference	+5 V reference
A-IN5	Tube Fill Status	A digital logic signal (high state > 2.5 V, low state <2.0 V.) When this signal is high, low tube voltage is indicated, and the tube requires a fill. If the autofill switch is on, or, if the switch is off and tube voltage is below the safety level, the fill system will be filling the tube while this signal is high. When this signal toggles from high to low continuously (1 Hz square wave), an empty gas reservoir is indicated and the tube can no longer be operated. When the signal is constantly low, tube voltage is OK.

Input Signal	Name	Description
A-IN6	Preamp Monitor 2	see below
A-IN7	Preamp Monitor 1	see below
A-IN8	Preamp Monitor 0	A-IN6, 7, and 8 are digital logic signals (high state > 2.5 V, low state < 2.0 V.) The combination of the three signals indicates the active power range according to the following table:

A-IN6	A-IN7	A-IN8	Power Range
low	low	high	0.3 W
low	high	low	1.0 W
low	high	high	3.0 W
high	low	low	10 W
high	low	high	30 W

Analog Output Definitions

Output Signal	Name	Description
A-OUT1	Current Command	A signal that selects the desired tube current when the laser is operated in current mode. 0 to +5 V represents 0 to 100 A tube current.
A-OUT2	Power Command	A signal (0 to +5 V full scale) that selects the desired optical output power when the laser is operated in the power mode. The full scale value of the command is determined by the active power range as shown in the table below:

A-OUT2	Power Range
0 to 0.316 W	0.3 W
0 to 1.0 W	1.0 W
0 to 3.16 W	3.0 W
0 to 10 W	10 W
0 to 31.6 W	30 W

I/O Connector Diagram

Computer Interface Board		J1		To 2570 Power Supply Grounded Control PCB
Analog Inputs	A-IN1	18	←------	Voltage Monitor
	A-IN2	19	←------	Current Monitor
	A-IN3	20	←------	Power Monitor
	A-IN4	21	←------	+5V Reference
	A-IN5	33	←-----	Tube Fill Status
	A-IN6	32	←------	Preamp Monitor 2
	A-IN7	31	←------	Preamp Monitor 1
	A-IN8	30	←-----	Preamp Monitor 0
Analog Outputs	A-OUT1	17	------→	Current Command
	A-OUT2	34	------→	Power Command
Status Port 4	DIG40	9	←------	Keyswitch Interlock OK
	DIG41	10	←------	Head Cover Interlock OK
	DIG42	11	←------	Water Flow Interlock OK
	(msb) DIG43	12	←------	Water Temp Interlock OK
Status Port 5	DIG50	13	←------	Auxiliary Interlock OK
	DIG51	14	←------	Regulator Interlock OK
	DIG52	15	←------	Magnet Monitor 1
	(msb) DIG53	16	←------	Magnet Monitor 0
Control Port 6	DIG60	42	------→	Preamp Select 0
	DIG61	41	------→	Preamp Select 1
	DIG62	40	------→	Preamp Select 2
	(msb) DIG63	39	------→	Mode
Control Port 7	DIG70	38	------→	Plasma On/Off
	DIG71	37	------→	n.c.
	DIG72	36	------→	n.c.
	(msb) DIG73	35	------→	Auto Fill System Enable

Programming Example

(Written using MS-DOS Basic on the Radio Shack TRS-80 MODEL 100 computer)

This program continuously runs the Model 2570 power supply through the following seven minute plasma on and off cycle:

MINUTE	PLASMA	CURRENT
1	on	50 A
2	on	20 A
3	on	50 A
4	on	modulated
5	on	50 A
6	off	0 A
7	off	0 A

10	CLS	
20	PRINT "2570 TEST"	
30	OPEN "COM:78N2D" FOR OUTPUT AS 1	Initialize RS-232 port to 4800 baud, 8-bit character, no parity, 2 stop bits, XON/XOFF disabled
40	PRINT#1,""	Clear computer interface board (CIB) RS-232 port
50	PRINT#1, "WRITE 6,8"	Initialize CIB port 6
60	PRINT#1, "WRITE 7,1"	Initialize CIB port 7
70	PRINT#1,"CONFIGURE 6,OUT, NON"	Configure CIB port 6
80	PRINT#1,"CONFIGURE 7,OUT, NON"	Configure CIB port 7
90	PRINT#1,"SET1,125"	Set current control high
100	PRINT#1,"WRITE 7,0"	Turn on plasma
110	GOSUB 300	Wait 1 min
120	PRINT#1,"SET1,50"	Set current control low
130	GOSUB 300	Wait 1 min
140	PRINT#1,"SET1,125"	Set current control high
150	GOSUB 300	Wait 1 min
160	FOR X = 1 to 400	Start 1 min modulation
170	PRINT#1,"SET1,125"	Set current control high

```
180   FOR Y = 1 to 25              Delay
190   NEXT Y
200   PRINT#1,"SET1, 50"           Set current control low
210   FOR Y = 1 to 25              Delay
220   NEXT Y
230   NEXT X                       End modulation loop
240   PRINT#1,"SET1, 125"          Set current control high
250   GOSUB 300                    Wait 1 min
260   PRINT#1,"WRITE 7,1"          Turn off plasma
270   GOSUB 300                    Wait 2 min
280   GOSUB 300
290   GOTO 110                     Repeat 7 min cycle
300   FOR X = 1 to 21700           1 min delay subroutine
310   NEXT X
320   RETURN
330   END
```

Chapter 7 Maintenance

Notes on the Cleaning of Laser Optics

Ion lasers are oscillators that operate with gain margins of a few percent. Losses due to unclean optics, which might be negligible in ordinary optical systems, can disable a laser. Dust on mirror surfaces can reduce output power or cause total failure. Cleanliness is essential, and the maintenance techniques used with laser optics must be applied with extreme care and attention to detail.

"Clean" is a relative description; nothing is ever perfectly clean, and no cleaning operation ever completely removes contaminants. Cleaning is a process of reducing objectionable materials to acceptable levels.

Since cleaning simply dilutes contamination to the limit set by solvent impurities, solvents must be as pure as possible. Use spectroscopic, electronic, or reagent grade solvents, and leave as little solvent on the surface as possible. As any solvent evaporates, it leaves impurities behind in proportion to its volume. Avoid rewiping a surface with the same swab; a used swab and solvents will redistribute contamination, they won't remove it.

Both methanol and acetone collect moisture during prolonged exposure to air. Avoid storage in bottles where a large volume of air is trapped above the solvent; instead, store solvents in squeeze bottles from which trapped air can be removed.

Laser optics are made by vacuum–depositing microthin layers of materials of varying indices of refraction on glass substrates. If the surface is scratched to a depth as shallow as 0.01 mm, the operating efficiency of the optical coating will be reduced significantly.

Stick to the following principles whenever you clean any optical surface.

- Remove and clean one optical element at a time. If all of the optics are removed and replaced as a group, all reference points will be lost, making realignment extremely difficult.
- Work in a clean environment, over an area covered by a soft cloth or pad.

- Wash your hands thoroughly with liquid detergent. Body oils and contaminants can render otherwise fastidious cleaning practices useless.
- Use dry nitrogen, canned air, or a rubber squeeze bulb to blow dust or lint from the surface before cleaning with solvent. Permanent damage may occur if dust scratches the glass or mirror coating.
- Use spectroscopic, electronic, or reagent grade solvents. Don't try to remove contamination with a cleaning solvent that may leave other impurities behind.
- Use photographic lens tissue to clean optics and plasma tube windows. Use each piece only once: dirty tissue merely redistributes contamination, it doesn't remove it.

Cleaning Prisms And Mirrors

Equipment Required:

- dry nitrogen, canned air, or rubber squeeze bulb
- photographic lens tissue
- spectroscopic grade acetone
- forceps
- hemostats

Cleaning Mirrors

1. Remove the mirror assembly from its mounting plate. The broadband high reflector can be cleaned without removing it from its holder. All other mirrors must be hand-held; use finger cots for protection.
2. Hold the mirror horizontal with its coated surface up and squeeze a drop or two of acetone onto it. Place a piece of lens tissue on the wetted surface and gently draw it across to remove dissolved contaminants.
3. If the mirror is an output coupler, invert it and repeat, cleaning the second surface.
4. Install the mirror and adjust the mirror mount for maximum optical output power.

Figure 7–1: Cleaning the Mirror Surface

Cleaning the Prism Assembly

1 Unscrew the retaining ring and lift the prism mount from its protective cup.

A small screw holds the mirror-retaining spring in place (Figure 5–5). Remove it and invert the assembly, dropping the mirror onto a soft surface. Clean the mirror as described in the preceding section.

2 Remove the prism shield but leave the prism alone; it can be cleaned in its mount.

3 Blow away dust particles or lint using nitrogen or air.

4 Fold a piece of lens tissue into a pad about 1 cm on a side and clamp it in a hemostat (Figure 7–2). Saturate the pad with acetone, shake off the excess, resaturate, and shake again.

5 Wipe one surface – bottom to top – in a single motion. Be careful that the tip of the hemostat does not scratch the surface. Repeat the operation with a clean tissue on the second prism surface. A clean prism surface will scatter little or no light when the laser is operating.

6 Install the prism assembly and adjust the mirror vertically and horizontally for maximum optical output power.

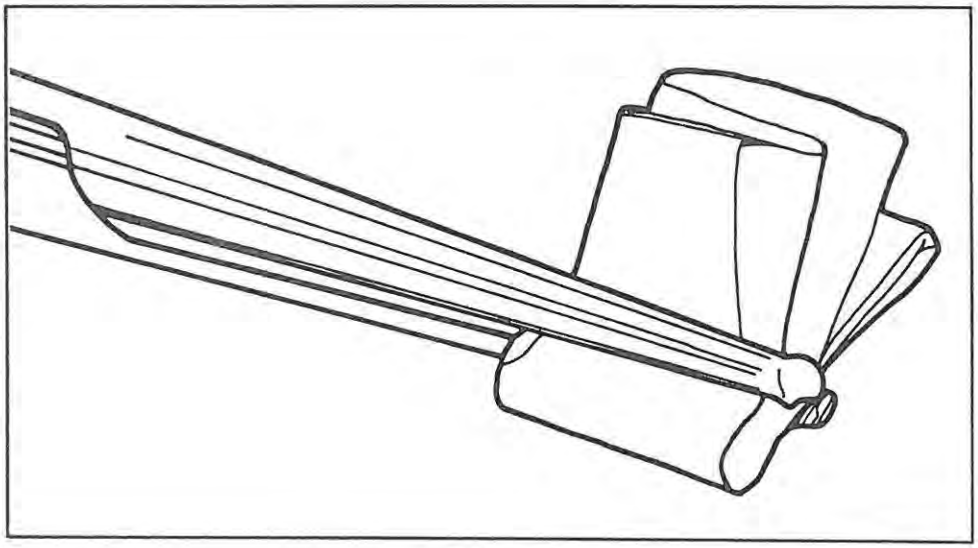


Figure 7-2: Lens Tissue Folded for Prism Cleaning

Replacing the Water Filter

1. Shut off the water supply. Place a bucket or container under the filter to catch any spilled water.
2. Press the button on top of the filter housing to release internal pressure.
3. Unscrew the lower portion of the filter housing.
4. Remove the used filter.
5. Make sure the O-ring at the top of the housing is clean and seated evenly in its groove.
6. Insert the new filter and install the lower housing.

Replacing the Purge Filter

When the dessicant in the purge filter turns pink or red, the filter container should be replaced. Replacement filters are available from Spectra-Physics, the part number is 0431-4570.

1. Turn off the laser.
2. Remove the screws (4) that secure the PURGE FILTER SYSTEM STATUS panel to the power supply, then remove the panel.
3. Pull the filter container out of power supply by tilting it out from the top first, then lifting it out.
4. Disconnect the purge hose from the fitting on the top of the filter container. Mark this hose with a piece of tape so you can connect it to the top fitting on the new filter container.

5. Disconnect the purge hose from the fitting on the side of the filter container.
6. Connect the purge hoses to the same fittings on the new filter container.
7. Install the filter container in the power supply. Be sure the purge hoses are not pinched or crimped after the filter container is in place.
8. Secure the panel to the power supply using the screws (4).

Chapter 8 Service and Repair

DANGER
The following procedures require removal of the laser head cover and defeat of its safety interlock. Dangerous laser radiation is accessible when cavity seals are pulled back; therefore, permit only trained personnel to service and repair your laser system.

The Model 2040 resonator is designed so the center of the aperture and the centers of the front and rear mirror mounts lie on the same line – the resonator axis. In order for the laser to provide optimum performance, three conditions must be met:

- the line defined by the plasma tube bore must be centered on the resonator axis;
- the flat high reflector must be perpendicular to the resonator axis;
- the center of curvature of the output coupler must be on the resonator axis.

Your laser is factory aligned and, under normal operating conditions, should only require the preventive practices described in "Maintenance" to meet its performance specifications. If you discover a significant drop in power that can't be restored by mirror cleaning, the source of the problem is probably one of the following:

- unclean plasma tube windows,
- misaligned optics,
- misaligned plasma tube.

The procedures in this section allow you to solve these problems, thereby returning your laser to optimum performance. They are provided in the order in which you should perform them. The most probable cause of poor performance is contaminated optics; therefore, they should be cleaned before you try anything else. If the problem persists after cleaning the mirrors, clean the plasma tube windows. Then align the optics, if necessary. Finally, if all else fails, align the plasma tube.

These procedures are progressive in nature. If you achieve success at the end of one procedure, you don't need to go on to the next.

If the laser has been cleaned and aligned and you are sure that it is producing maximum power, but its performance remains below specification, call your Spectra-Physics service representative.

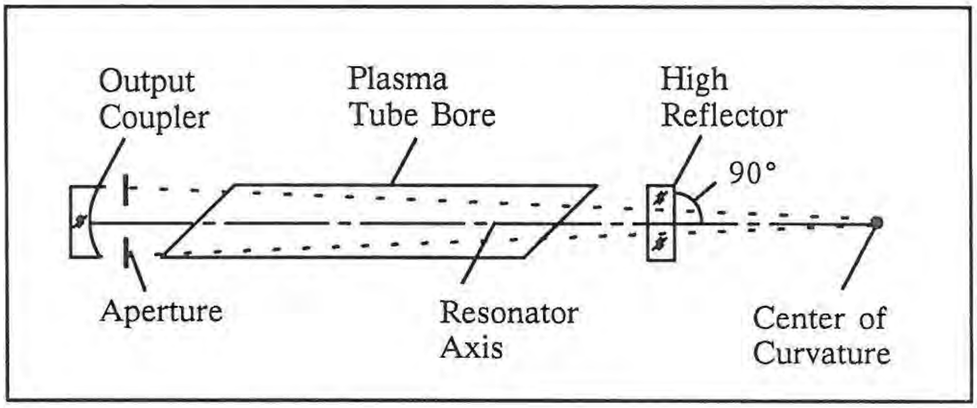


Figure 8–1: Schematic Representation of Ideal Resonator Alignment

Cleaning Plasma Tube Windows

This is a progressive procedure designed to enable you to remove even the most stubborn contaminating films. If you achieve success before you complete all of the steps, those that remain are optional. Having begun a numbered step, be sure you follow it through to completion. Failure to do so may leave additional contamination on the window surface.

Equipment Required

- forced air supply or dry nitrogen
- photographic lens tissue
- cotton swabs
- hemostat
- deionized or distilled water
- hydrogen peroxide (H_2O_2), 5% solution
- prerinse solution, composed of:

  1 part nitric acid (HNO_3)

  19 parts deionized water

  17 parts methanol (CH_3OH)

- Calcium Carbonate ($CaCO_3$) - primary standard powder, 600+ mesh—per American Chemical Society specifications Mallinckrodt 4071, 4072 or equivalent
- Micro Detergent™, manufactured by:
  International Products Corporation
  P.O. Box 118 Trenton, New Jersey 08601
- three empty bottles to hold the cleaning solutions listed below

A kit comprising the above materials is available from Spectra–Physics (part number 0000–0013).

Cleaning Solutions Required

- spectroscopic grade acetone (CH_3COCH_3)
- spectroscopic grade methanol (CH_3OH)

Procedure

1. Carefully pull back the cavity seal, then use compressed air or dry nitrogen to blow away dust particles and lint.
2. Fold a piece of lens tissue into a pad about 1 cm on a side and clamp it in a hemostat (Figure 7–2). Saturate the pad with methanol, shake off the excess, resaturate, and shake again.

   Wipe the window with a single stroke from bottom to top. Most contamination can be removed with this step alone.
3. Fold another tissue and saturate it with acetone, as above. Wipe the window again.

   Follow the acetone with a methanol wipe using a clean tissue pad.
4. Saturate a cotton swab with 5% hydrogen peroxide; use a circular motion to clean the entire window surface.

   Follow the peroxide with a methanol wipe using a clean tissue pad.
5. Use a cotton swab to wet the entire window with prerinse solution. Dip the swab, wet with prerinse, lightly into calcium carbonate powder; the resulting paste should have the consistency of toothpaste. Scrub the window surface, using a circular motion, for about 30 sec. Do not allow the calcium carbonate to get onto the side of the window or endbell where it could get lodged in the cavity seal and cause contamination problems.

6. Dip a dry cotton swab in the calcium carbonate powder and scrub the window again. The additional powder will dry the paste remaining from the previous step.

   Rinse with a cotton swab saturated with prerinse solution.

7. Saturate a cotton swab with Micro Detergent™ and clean the mirror surface using a circular motion.

8. Rinse the surface three times using cotton swabs saturated with deionized water.

9. Follow the deionized water with a methanol wipe using a clean tissue pad.

10. Install the cavity seal and make sure the air purifier is turned on.

Vertical Search Alignment Procedure

If your instrument fails to lase, the source of the problem could be a severely misaligned high reflector. The following technique allows you to readily restore lasing.

Remove the top cover from the laser head and open the aperture fully ("12" on the scale). Install the interlock defeat key.

Turn the coarse vertical adjustment two turns counterclockwise. Grasp the high reflector mirror mounting plate near the coarse vertical adjustment screw and rock the mounting plate back and forth; simultaneously, turn the coarse horizontal adjustment to scan the high reflector horizontally. Keep rocking and scanning until you observe a bright flash of laser light. When the beam flashes, stop turning the horizontal control; then turn the vertical adjustment clockwise until you establish sustained lasing.

Figure 8–2: Vertical Search Technique

If you turn the horizontal adjustment so far that you are convinced that you will never achieve lasing, turn it in the other direction. Keep rocking the mirror mount as you turn the control.

Mirror Alignment

Patience and attention to detail are required to assure proper alignment. First, the laser must be tuned for apparent maximum power. Then the beam must be "walked" along the parallel mirrors until you have satisfied yourself, by trial and error, that no additional power can be coaxed from the unit.

Adjusting the Mirrors for Apparent Maximum Power

1. Insert a #23 (3/32 in.) driver in the coarse horizontal adjustment. Use the coarse vertical adjustment as the second control for this step.
2. Monitor the output power while you turn one coarse control, moving it back and forth until the output is as high as possible. Then adjust the other coarse control.
3. Repeat the adjustments, first turning one control, then the other, back and forth until the power reaches its maximum.
4. Repeat with the fine mirror adjustments. Make a note of the output power.

"Walking the Mirrors" to Assure Maximum Power

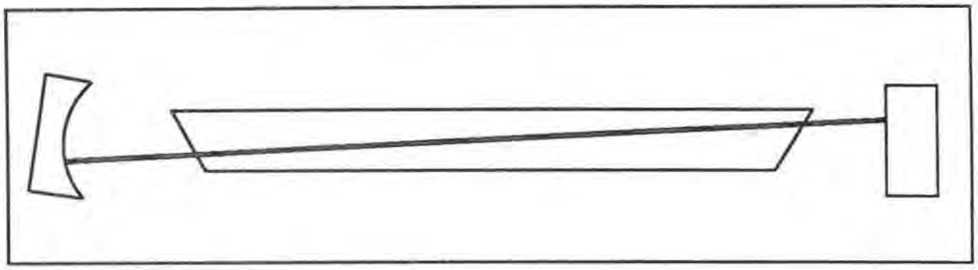


Figure 8-3: Misaligned Mirrors Allow Lasing at Reduced Power

Figure 8-3 illustrates an arrangement of cavity mirrors that will allow lasing, but with reduced output. A slight tilt of the high reflector compensates for a similar tilt of the output coupler. The resulting beam is skewed with respect to the resonator axis and the plasma tube bore. Under these conditions the laser can be "peaked," but the output will be less than optimum because part of the beam is obstructed by the bore walls.

Walking the mirrors is a trial and error procedure that assures optimum mirror alignment. The goal is to align the intracavity beam with the resonator axis by making small adjustments of the high reflector and matching them with adjustments of the output coupler. By observing the change in output power as you move the mirrors, you will find the optimal alignment positions.

1. Once the high reflector has been adjusted for maximum power, detune one of its coarse controls until the output is about half its maximum value. Move to the other end of the laser and turn the corresponding output coupler control in the same direction.

   Be careful! Use the same controls on both ends of the laser and turn them the same direction: if you turn the high reflector vertical control clockwise, turn the output coupler vertical control clockwise (keeping the same point of view). If you lose lasing, reverse the direction of mirror movement until lasing is restored.

2. Observe the change in output power as you turn the output coupler control. If the output maximum exceeds the original value, walk the mirrors in the same direction again. Repeat until the power reaches its maximum.

3. If the output fails to reach the original value, return both controls to their original positions.

4. Adjust the high reflector for maximum power.

5. Walk the mirrors with the other pair of controls. If you first walked the vertical mirror controls, do the same with the horizontal controls or vice-versa.

   Remember, always walk the mirrors in the direction of increased output power. If the power starts to decline, go the other way. And always find the maximum power with one set of controls before moving to the other set: finish with the vertical controls before you move the horizontal controls and vice versa. Always adjust the high reflector for maximum power before changing from one set of controls to the other.

6. Repeat the walking process several times, first with one set of controls, then with the other. Continue until the output power is as high as it can go.

Plasma Tube Alignment

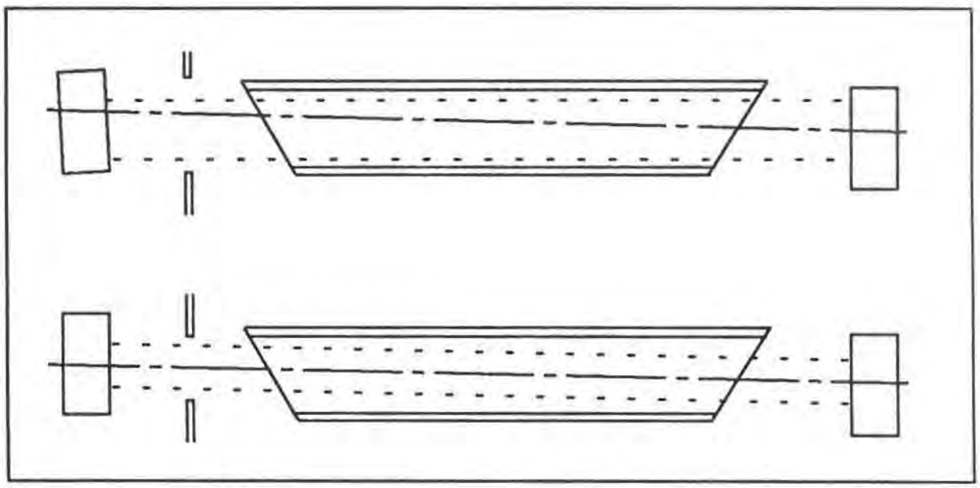


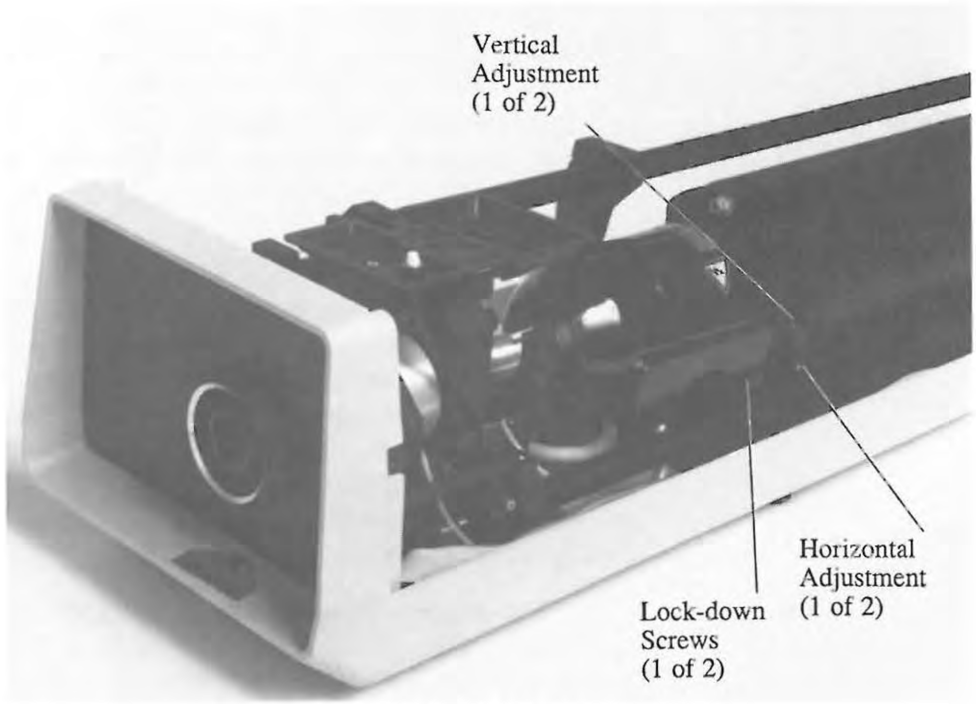
Figure 8-4: Misaligned Plasma Tube Allows Lasing at Reduced Power

Figure 8-4 illustrates two arrangements where the plasma tube is misaligned with respect to the resonator axis. In the first, the tube is skewed and the mirrors have been aligned to compensate. In the second, the cavity mirrors are aligned for optimum output but the tube is skewed. Both problems cause a power loss, the first because the beam does not travel through the center of the aperture. Closing the aperture will cause a significant loss as the aperture wheel partially obstructs the beam. The second causes a power loss because the beam is partially obstructed by the bore walls.

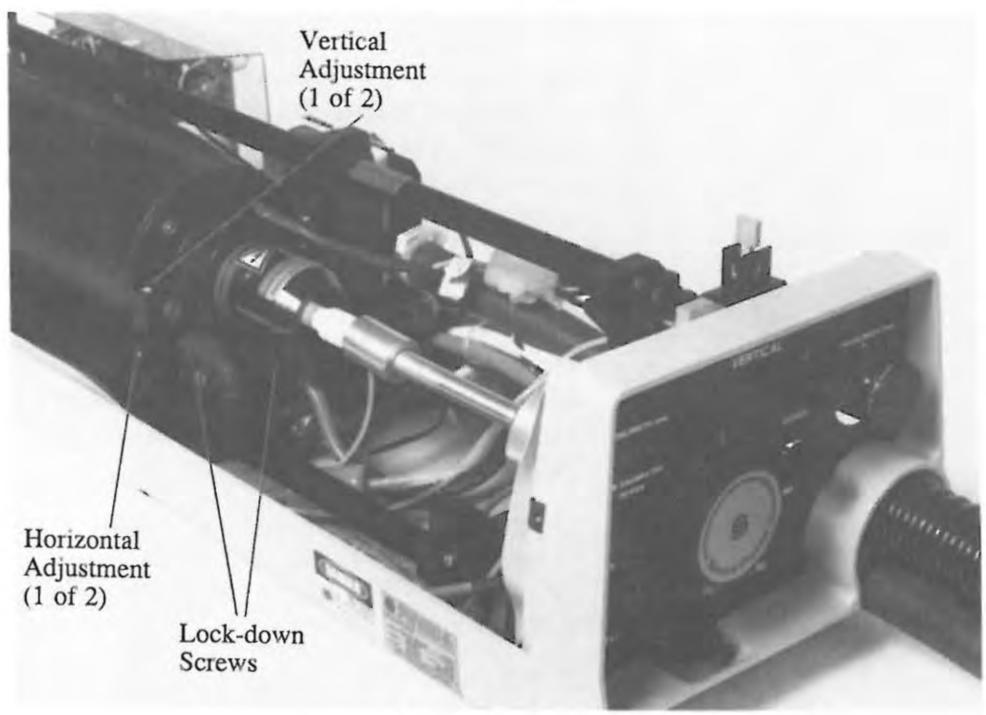
The following procedures center the plasma tube bore on the resonator axis, thereby enabling the laser to produce maximum output power. Use an external power meter to monitor the alignment of the plasma tube.

DANGER: HIGH VOLTAGE AND CURRENT
The locking screws described below lie dangerously close to the anode and cathode terminals, and their voltage and current levels are lethal. Be sure to shut down the system before attempting to loosen the magnet mounting screws.

1. Carefully pull back the cavity seals at both ends of the tube.
2. Tighten all eight adjustment screws (Figure 8–5) against the magnet carriage, then loosen the locking screws at each end of the carriage.
3. Start the laser. Then adjust the horizontal position of the plasma tube at the cathode end, working one adjusting screw against the other, until you achieve maximum output power. Move to the anode end and repeat, adjusting the horizontal position of the plasma tube.
4. Adjust the vertical position of the anode end for maximum power, then move to the cathode end and repeat.
5. Repeat the adjustment sequence until no further increase in power occurs: the plasma tube alignment is "peaked".
6. Reduce the current to the lowest value that will still allow lasing and observe the position of the beam on the high reflector. If the beam is not centered, move it by walking the mirrors. Determine the axis, either horizontal or vertical, along which the beam must travel and adjust the appropriate controls. Monitor the output power as you walk the beam toward the center of the mirror. If the power drops significantly, adjust the tube position to repeak the output power.



Cathode End



Anode End

Figure 8–5: Plasma Tube Alignment Adjustments

7. Tube and mirror adjustments interact with one another, so you will probably find it necessary to repeat the sequences several times, first walking the mirrors, then moving the tube, then walking the mirrors again, ... After several iterations you will reach a point where the last possible milliwatt has been coaxed from the laser.

Aligning on the Aperture

This sequence insures that the beam will travel directly through the center of the aperture, which is mounted between the plasma tube and the output coupler. It is different from the factory alignment procedure, which requires special fixtures and tools that keep the beam in the center of the high reflector as well. Since it does not insure precise centering on the high reflector, the interchangeability of single-line prisms may suffer. You may also notice a slight overall power loss.

Clean the plasma tube windows; an acetone wipe followed by a methanol wipe should be sufficient (see "Cleaning Plasma Tube Windows" for details).

NOTE
Because thermal effects in intracavity spaces affect the beam, this final cavity alignment sequence should be done with the cavity in its operating condition. Before you install the cavity seals, however, check the position of the beam as it enters the high reflector mirror mount. It should be as close to the center of the opening as possible.

1. Adjust the high reflector for maximum output power; don't do anything else. Make a note of the maximum power.
2. Close the aperture until the power drops to about 80% of the maximum value, then readjust only the high reflector for peak output power.
3. Open the aperture wide and make a note of the power. If the beam is centered on the aperture, the new output value should be at least 97% of the old value; if it is, proceed to "Magnet Lockdown".

   If the new output value is less than 97% of the old value, continue with this procedure.
4. Adjust the high reflector for maximum power with the aperture wide open; make a note of the value.

5. Close the aperture until the power drops to less than 80% of the maximum value, then adjust the high reflector again to peak the output power.
6. Open the aperture wide and adjust the tube position for maximum power; make a note of the output.
7. Close the aperture until the output drops to 80% and readjust the high reflector for peak power. Open the aperture wide and check the output. If the second value is at least 97% of the first, turn to "Magnet Lockdown". If it is less than 97%, repeat the above alignment sequence.
8. Continue the check-and-align procedure until the beam is centered on the aperture, then proceed to "Magnet Lockdown".

Magnet Lockdown

Once the plasma tube and mirrors are aligned, the magnet/tube assembly can be locked into its final position. Check the power once more before beginning the locking sequence.

DANGER: HIGH VOLTAGE AND CURRENT
The locking screws lie dangerously close to the anode and cathode terminals, whose voltage and current levels are lethal. Be sure to shut down the system before approaching these screws.

1. Tighten the four lockdown screws in a figure-eight pattern so all screws apply equal pressure at all times.
2. Repeat the "Aligning on the Aperture" checking sequence. If the power readings deviate by more than 3%, loosen the magnet, repeak the plasma tube and repeat the lockdown sequence.
3. As soon as you have locked down the magnet, loosen its horizontal and vertical adjusting screws about two full turns. This completes the kinematic isolation of the plasma tube.

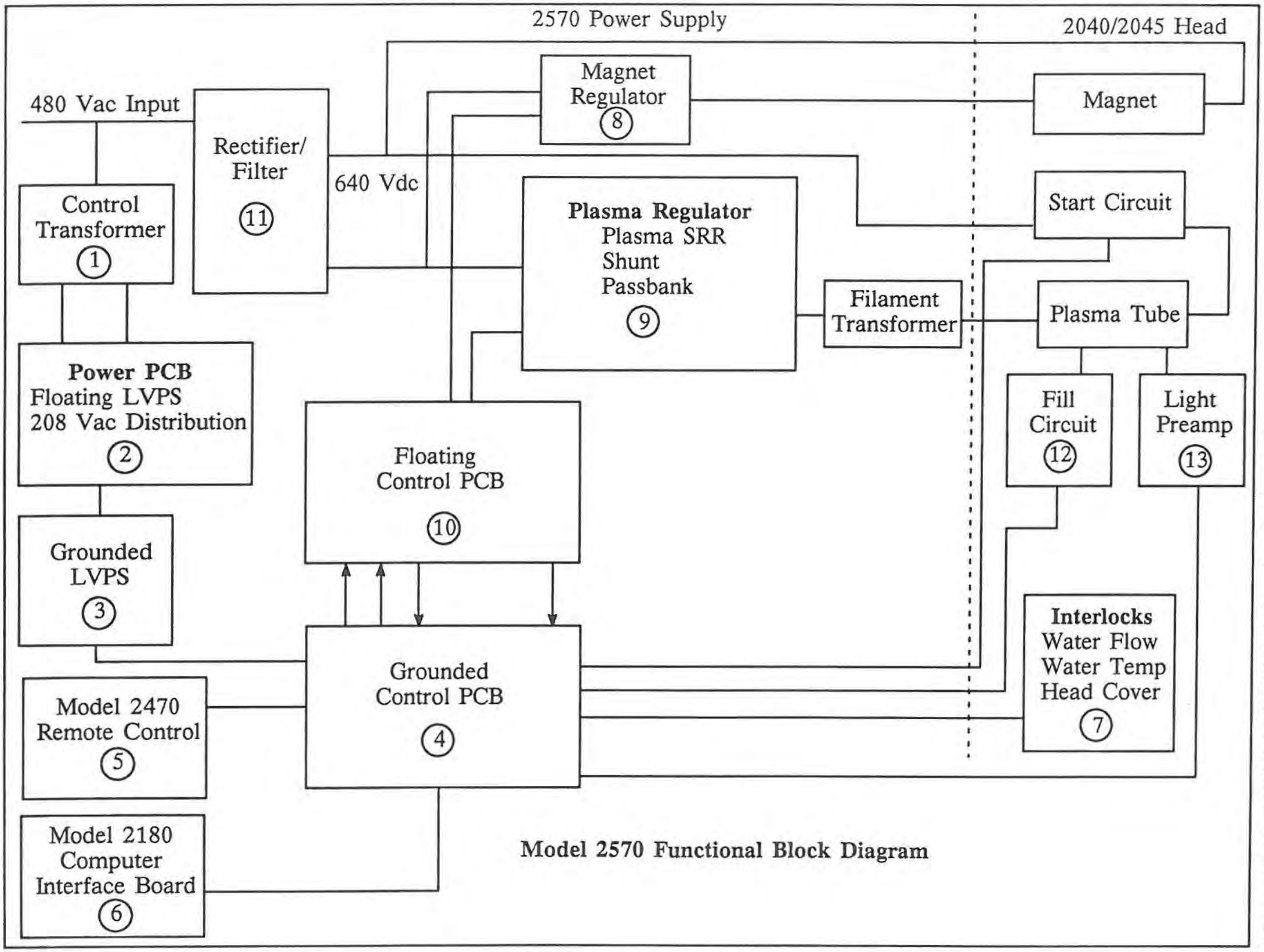


Figure 8–6: Model 2040/2570 Functional Block Diagram

The following circuit descriptions are provided to give an overview of system operation. The numbers for each description refer to their location in Figure 8–6.

Control Transformer (1)

This transformer operates continuously when power is supplied to the Model 2570. It provides 208 V ac and low voltage ac for the floating power supplies on the Power PC Board.

Power PC Board (2)

This board contains two floating low voltage power supplies. They are multi-output unregulated supplies that provide base current drive and power control circuits for the various regulators. The passbank supply is referenced to the emitter of the passbank transistor. The switched resistor regulator supply is referenced to the emitters of the plasma switched resistor regulator. These two supplies are called floating because they must float with respect to earth ground. They are at -325 V dc near the negative output of the main rectifier.

The Power PC board also contains the fusing and distribution of the 208 V ac to the grounded low voltage supply, the purge pump, the main contactor, and the start circuit in the head.

Grounded Low Voltage Power Supply (3)

This is a switching power supply that provides 5 V and ±12 V to power the grounded control circuitry.

Grounded Control PC Board (4)

This board provides the switching between remote and computer control, and also controls the interlock circuit, status latches, and turn-on sequence. Another function is to control the grounded current and power mode control loops.

Model 2470 Remote Control Module (5)

This unit plugs into the power supply and provides operator controls and monitor status. See Chapter 4 for complete information on the Model 2470.

Optional Model 2180 Computer Interface Board (6)

This board fits in the power supply over the top of the grounded control board. It provides RS-232-C or IEEE/488 control of the system.

Interlocks (7)

The water flow, water temperature, and head cover interlocks are located in the laser head. When any of these interlocks are open, the power supply is turned off and cannot be started again until all interlocks are closed.

Magnet Regulator (8)

This is a switched resistor regulator. The two darlington switch transistors are located in a single package on the cold plate.

The resistors are two of the elements of the eight element heater assembly. The capacitors are located on the capacitor board and the base drive and control circuitry is on the floating control board.

Plasma Regulator (9)

The plasma regulator is a composite system consisting of the plasma switched resistor regulator (SRR), the shunt regulator, and the passbank regulator.

The plasma SRR is a four phase system utilizing two dual transistor packages on the outside of the cold plate, four heater elements of the eight element heater, and capacitors on the capacitor board.

The shunt regulator uses two large darlington transistors on the inside of the cold plate connected in series across the SRR. The minimum current resistors are in series with each other and connected in parallel with the SRR. The midpoint provides the bias voltage to equalize the voltage between the two shunt regulator transistors.

The passbank regulator consists of one transistor connected in series with the SRR and shunt regulators. It provides limited range fast regulation capability. The SRR and shunt regulators are controlled to keep the passbank within its compliance range.

Floating Control Board (10)

This board provides all drive signals to the various regulators. It is called floating because except for a small band of circuitry at the end of the board near the grounded control board, the circuits are referenced near the negative side of the rectified 480 V ac power (-325 V dc) instead of earth ground. Functions of the floating control board include:

- magnet regulator control circuitry
- plasma regulator control and coordination circuitry
- voltage and current monitors
- floating power supply check circuit

Rectifier/Filter Section (11)

This section includes the main contactor, three phase full wave bridge main rectifier, filter inductor, filter capacitor bank, surge limit circuit, and bleeder resistors. It provides 650 V dc at 80 A unregulated to power both the plasma and magnet regulators.

Fill Circuit (12)

This circuit, located in the laser head, uses plasma voltage and current monitor signals from the power supply along with information from the fill board (corresponding to tube type) to determine the correct tube voltage. If a fill is required, it provides the proper sequence of solenoid operations to fill the tube.

Light Preamp (13)

This circuit, located at the front of the laser head, has electronically variable gain, dependent on operating wavelength and power range selection.

Troubleshooting

The following information is provided to assist in isolating some of the problems that might arise in the power supply or laser head. A complete repair procedure is beyond the scope of this manual. For information concerning repair by Spectra-Physics, see "Customer Service."

DANGER
The laser head and power supply of this system contain electrical circuits operating at high voltages. Whenever access to the interior of the laser head or power supply is necessary and laser operation is required, exercise extreme caution to avoid contact with high voltages. These high voltages are lethal.

Symptom: Low output power

- Dirty optics or plasma tube windows. See corresponding sections in "Maintenance" and "Service and Repair."
- Incorrect optics. Check that the optics in the laser are coated for the wavelength you are using.
- Error in setting. Check for correct current setting, and make sure that the aperture and shutter are both open. Be sure you are tuned to a strong line and that the power range setting is not limiting the power output if you are in power control mode.

- Plasma tube or mirrors misaligned. See "Service and Repair: Mirror Alignment" and "Plasma Tube Alignment."

Symptom: Maximum current too low.

- Possible high tube pressure. Check the tube voltage on the remote control module. If the voltage is over 600 V, contact your Spectra Physics service representative.
- Possible low line voltage. If the line voltage is below 442 V, maximum current may not be available.

Symptom: Plasma discharge ceases.

- Possible open interlock. Check the water flow, water pressure and water temperature. Also check laser head and power supply interlocks.

Replacement Parts

Description	Part Number
Purge Filter	0431-4570
Water Filter	2604-0070
Fuse, 15 A, 250 V, S.B.	5101-0760
Fuse, 8 A, 250 V, S.B.	5101-1020
Fuse, 1 A, 250 V, ceramic dual element	5101-1430
Fuse, 80 A, 600 Vac	5101-1590
Fuse, 20 A, 600 V, F.B.	5101-1600
Fuse, 1 A, 500 V, S.B. dual element	5101-1640

Chapter 9 Customer Service

At Spectra-Physics, we take pride in the durability of our products. Considerable emphasis has been placed on controlled manufacturing methods and quality control throughout the manufacturing process. Nevertheless, even the finest precision instruments will need occasional service. We feel that our instruments have favorable service records compared to competitive products. We hope to demonstrate, in the long run, that we provide excellent service to our customers in two ways. First, by providing the best equipment for the money, and second, by offering service facilities that restore your instrument to working condition as soon as possible.

Spectra-Physics maintains major service centers in the United States, Europe, and Japan. Additionally, there are field service offices in major United States cities. When calling for service inside the United States, dial our toll-free number: (800) 323-8686. To phone for service in other countries, refer to the Service Centers listing located at the end of this section.

Replacement parts should be ordered directly from Spectra-Physics. For ordering or shipping instructions or for assistance of any kind, contact your nearest sales office or service center and give the instrument model and serial numbers. Service data or shipping instructions will be promptly supplied.

Warranty

The Model 2040 system is protected by a 12-month/1500 hour warranty. All mechanical, electronic, and optical parts and assemblies, including plasma tubes, are unconditionally warranted to be free of defects in workmanship and material for the warranty period. At its election Spectra-Physics will repair or replace without charge components that prove defective during the warranty period. The obligation of Spectra-Physics is limited to such repair under the warranty return procedure described below. Equipment that has been repaired or replaced will be warranted only for the remaining portion of the original warranty period.

Warranty extensions for incremental 6-month/750 hour periods can be purchased before the expiration date of any prior warranty.

This warranty is in lieu of all other warranties, expressed or implied, and does not cover incidental or consequential loss.

Spectra-Physics will provide at its expense all parts and labor and one way return shipping of the defective part or instrument (if required).

This warranty does not apply to equipment or components that inspection by Spectra-Physics discloses to be defective or unworkable because of abuse, mishandling, misuse, alteration, negligence, improper installation, damage in transit, or other causes beyond the control of Spectra-Physics.

Return of the Instrument for Repair

Contact your nearest Spectra-Physics field sales office, service center, or local distributor for shipping instructions or an on-site service appointment. You are responsible for one-way shipment of the defective part or instrument to Spectra-Physics.

We encourage you to use the special Spectra-Physics packing boxes to secure instruments during shipment. If shipping boxes have been lost or destroyed, we recommend that you order new ones. Spectra-Physics will only return instruments in Spectra-Physics' containers.

Always drain cooling water from the laser head, magnet, and plasma tube before shipping. Water expands as it freezes, and damage incurred is excluded from warranty coverage.

See the list of Service Centers on the following pages.

Service Centers

Australia

Spectra-Physics Pty. Ltd.
2-4 Jesmond Rd.
Croydon, Victoria 3136
Tel: (03) 723-6600
Telex: AA 33498
Fax: (03) 725-4822

Belgium

Spectra-Physics B.V.B.A.
North Trade Building
Noorderlaan 133
2030 Antwerp
Tel: (03) 541-7515
Telex: 34467

Canada

Spectra-Physics Ltd.
1510 Drew Road, Unit 16
Mississauga, Ontario L5S 1W7
Tel: (416) 671-4180
Fax: (416) 671-2395

Latin America and Pacific Region

Spectra-Physics International
1250 West Middlefield Road
P.O. Box 7013
Mountain View, CA 94039-7013
Tel: (415) 961-2550
Telex: 348-488
Fax: (415) 969-4084

France

Spectra-Physics SA
Avenue de Scandinavie
ZA de Courtaboeuf
BP 28-91941 LES ULIS Cedex
Tel: 1.6907 99 56
Telex: 691183
Fax: 1.6907 60 93

Service Centers *(cont.)*

F.R. Germany and Export Countries*

Spectra-Physics GmbH
Siemensstrasse 20
D-6100 Darmstadt
F.R. Germany
Tel: (06151) 708-0
Telex: 419471
Fax: (06151) 7 50 00

Hong Kong

Spectra-Physics
Shun Ho Tower, 6th Floor
24 Ice House Street
Tel: (852) 5-264183
Telex: 67472
Fax: (852) 5-8684317

Italy

Spectra-Physics SRL
Centro Direzionale Lombardo
Palazzo E—Building E
Via Roma, 108
20060 Cassina De' Pecchi (MI)
Tel: 02-95300600
Fax: 02-95300609

Japan

Spectra-Physics KK
15-8 Nanpeidai-cho
Shibuya-ku, Tokyo 150
Tel: (03) 462-4531
Telex: 2466976
Fax: (03) 462-4530

* *CSSR, Denmark, Egypt, Finland, Greece, Ireland, Israel, Kuwait, Norway, Pakistan, Portugal, Saudi Arabia, South Africa, Spain, Sweden, Turkey, USSR, and Yugoslavia.*

Service Centers *(cont.)*

The Netherlands

Spectra-Physics BV
Prof Dr Dorgelolaan 20
P.O. Box 2264
5600 CG Eindhoven
Tel: (040) 45 18 55
Telex: 51668
Fax: (040) 43 99 22

Switzerland

Spectra-Physics AG
Hegenheimermattweg 65
CH-4123 Allschil/Basel
Tel: (061) 63 84 00
Fax: (061) 63 37 44

United Kingdom

Spectra-Physics Ltd
Boundary Way
Hemel Hempstead, Herts, HP27SH
Tel: (0442) 232322
Telex: 826411
Fax: (0422) 68538

Eastern United States

Spectra-Physics Inc
366 South Randolphville Road
Piscataway, NJ 08854-4175
Tel: (800) 323-8686
Fax: (201) 981-0029

Western United States

Spectra-Physics Inc
Laser Products Division
1250 West Middlefield Road
P.O. Box 7013
Mountain View, CA 94039-7013
Tel: (800) 323-8686
Telex: 348-488
Fax: (415) 969-4084

Spectra-Physics Instruction Manual–Problems and Solutions

We have provided this form to encourage you to tell us about any difficulties you have experienced in using your Spectra-Physics instruments or its instruction manual—problems that did not require a formal call or letter to our Service Department, but that you feel should be remedied. We are always interested in improving our products and manuals, and we appreciate all suggestions. Thank you.

From:

Name ______________________________

Company or Institution ______________________________

Department ______________________________

Address ______________________________

____

Instrument Model Number ______________ Serial Number ______________

Problem: ______________________________

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Suggested Solution(s): ______________________________

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Spectra-Physics, Inc.
LPD Technical Publications
P.O. Box 7013 MS 2-40
Mountain View, CA 94039-7013
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